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CHEMICAL SECTION.

Stated Meeting, held April 25, 1901.

SOME OF THE WORK OF W. SPRING, OF LIÈGE.

BY ROBERT H. BRADBURY,
Member of the Institute.

In reviewing the work of one man, the choice of subject-matter is determined entirely by the historical consideration. One encounters, therefore, the danger of becoming incoherent, of making sudden and violent transitions from one subject to another. In order to avoid this I will make no attempt to describe Spring's work completely, but will select those of his papers which deal with two special subjects, and not consider the others at all.

I.

Much of his later work is concerned with the color and transparency of liquids. He has shown that most so-called colorless liquids exhibit very distinct colors when light is made to pass through a sufficiently thick layer. Thus,

when water is examined in a tube 26 meters long, it is found to have a blue color, which can be closely imitated by a solution of $CuCl_2$ of proper concentration. This gives a simple answer to the old question as to the cause of the color of large bodies of water. It is the natural color of the water which makes its appearance, owing to the thickness of the layer examined. Suspended matter reflects equally light of all wave-lengths, and cannot, therefore, be instrumental in producing the blue color, as was at one time supposed. In agreement with this stands the fact that the color is most evident in waters free, or nearly free, from suspended substances.

It is interesting to notice that this faint blue tint appears to be dependent on the presence of oxygen in the substance. Liquid oxygen is distinctly blue; liquid ozone intensely so. In order to test this conclusion Spring undertook the difficult and dangerous operation of preparing large quantities of anhydrous hydrogen peroxide.* He found it to possess the same color as water, but in considerable greater intensity.

The same color appears in organic compounds containing hydroxyl. In this direction experimentation is rendered difficult by the fact that there are few compounds which can be obtained in the large quantities required without an almost prohibitory outlay. It seems that the natural color of the carbon chain is gold-yellow, and this color is seen in all liquid carbon compounds which do not contain hydroxyl. The presence of oxygen not as hydroxyl does not affect the color.† Thus acetone possesses the same yellow color as liquid hydrocarbons.

On the other hand, hydroxyl communicates to compounds containing it a blue color, and methyl or ethyl alcohol in a tube 26 meters long, is bluish green and more transparent than water.‡ As the carbon chain increases in length, the yellow triumphs over the blue of the hydroxyl group. Amyl

* *Zeit. Anorgan. Chem.*, Vol. 8, p. 424.
† *Bull. Acad. Belg.*, Third Series, 31, p. 246.
‡ *Bull. Acad. Belg.*, Third, Series 33, p. 165.

alcohol is yellowish-green. Another interesting point is the behavior of mixtures of miscible liquids. Each affects light passing through it as though it existed alone. The color produced by passing light through a mixture of two liquids A and B is exactly the same as that obtained when the light is caused to pass through a tube of A and then another of B placed end to end. Solutions of LiCl, KCl, KNO_3, $MgCl_2$, $CaCl_2$, $SrCl_2$, $BaCl_2$ possess the same color as water, but are less transparent. The amount of light stopped by a layer 26 meters in thickness increases with the concentration of the solution, but not proportionally.*

When a ray of light enters a dark room, through a chink in the shutter, the path of the light is visible. Every one is aware that this is due to the suspended matter of the air, and it is a familiar lecture experiment due, I believe, to Tyndall—to enclose some air over night in a glass box, the bottom of which has been smeared with glycerine. This catches the suspended matter and the track of a beam becomes perfectly invisible. Other gases behave in the same way when the suspended matter has been removed. Gases are said to be *optically empty* (optisch leer).

Now when a converging beam of electric light is passed into a liquid in a dark room the track of the light is brilliantly visible. There has been much discussion as to whether this effect is due to suspended matter, or to a peculiar property of liquid molecules of reflecting light sidewise. Spring settled this question by preparing water free from suspended matter. This cannot be done by distillation nor by filtration. Distillation of hydrant-water greatly increased the turbidity and filtration through raw cotton—which, when properly carried out, completely frees a gas from suspended matter—makes water more turbid than before. But when a suspension of silicic acid in water is placed in a U-tube and subjected to the influence of an electric current, the suspended particles proceed to the cathode, and the liquid about the anode becomes *optically empty*.† The path of a beam of light is just as invisible

* *Chemiker Zeitung*, Vol. 33, p. 375.
† *Bull. Acad. Belg.*, Third Series, 37, p. 174.

as in dust-free air. It is also possible to obtain optically empty water by purely chemical methods. Thus when ferric hydroxide or aluminium hydroxide is precipitated in water solution it catches and carries down the suspended particles and the liquid over the precipitate becomes optically empty. Crystalline precipitates like CaC_2O_4 or $BaSO_4$ have no effect. In preparing optically empty water, the air must be absolutely excluded, for a moment's air contact will charge the liquid richly with suspended matter.

So far it has been impossible to obtain an organic liquid in optically clear condition. Spring believes that the visibility of a beam of light in most liquids is due to the action of the liquid molecules upon the light, and not to suspended matter, but this point requires further investigation.

In *colloidal solutions* like those of the alkaline silicates, gum arabic, dextrine and gelatine in water, and alcoholic solutions of rosin, sandarach, and other resins, the path of the beam is always distinctly visible. This is another support for the modern conception which regards such "solutions" as simply suspensions of great fineness.

Salt solutions can be divided into two classes. Those of the alkalies and the alkaline earths, for instance, can be obtained optically clear just as readily as water itself. In those of Al, Cr, Fe, Cu and others the track of the beam remains obstinately visible. Hydrolysis—the reaction of the dissolved salt with water—supplies the explanation of this fact. When $Al\,Cl_3$ is dissolved in water the liquid is acid to litmus, inverts sugar and shows every evidence of the presence of hydrogen ions. Hydrochloric acid and $Al(OH)_3$ have been produced thus

$$Al\,Cl_3 + 3\,H_2O = Al\,(OH)_3 + 3\,HCl.$$

The $Al\,(OH)_3$ is colloidally dissolved and is responsible for the visibility of the light.

On the other hand, the hydroxides of the alkalies and alkaline earths are strong bases, there is no hydrolysis of their salts and no colloidally dissolved hydroxide to obstruct the passage of the light. Therefore the liquid remains optically clear.

Extremely suggestive, though preliminary in character and not directly connected with his other work, is Spring's proof that, in some way, the surface of a liquid is a seat of greater chemical activity than the interior portions.*

When a crystal of calcite dissolves partially in HCl, the crystalline form is not preserved. The angles are rounded off and grooves appear, especially in those surfaces which have been vertical or obliquely downward in the liquid so that the bubbles of CO_2 have had to slip along them on their way to the surface. This looks as though the presence of a gas bubble increased the action of the acid, and that

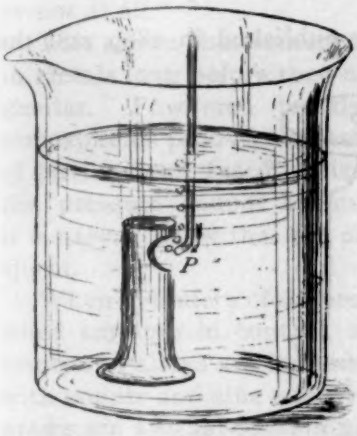

FIG. 1.

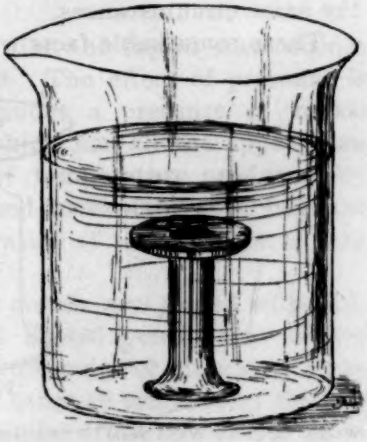

FIG. 2.

this is the case can be shown by supporting a slab of calcite vertically in HCl and leading a stream of CO_2 against it from a glass tube ending in a jet (*Fig. 1*).

A plate of calcite 2 m.m. thick is perforated at the point P, in a few minutes. This is not due to any chemical participation of the CO_2 in the reaction, for air and hydrogen produce exactly the same effect.

Probably the explanation that would occur to most people is that the gas current sets up a local vigorous stirring, constantly bringing new acid in contact with the

* *Zeit. Physikal. Chem.*, Vol. iv, p. 658.

surface. That this is not the true one can be shown by cementing a rim of wax to the upper end of a rod of calcite in such a way that the bubbles of CO_2 are held at rest (*Fig. 2*). The result is that the calcite next the wax is dissolved far more rapidly than the other portions, leading to a shape like that shown in *Fig. 3*.

Finally, if a slab of calcite is dipped half way beneath the surface of the acid, it is rapidly cut through at the surface of the liquid and the lower half falls to the bottom. The same behavior is shown by a liquid which only acts physically on a solid, for crystals of sugar, sodium carbonate and tartaric acid are rapidly cut in two by water under the same circumstances.

These remarkable facts were published in 1889, and the

FIG. 3.

work seems well worth following up. So far as I am aware, nothing farther has been done upon the subject.

II.

The second line along which Spring's activity has been exerted, is a subject which has occupied much of his scientific career and to which he has returned again and again. Briefly, the matter may be stated thus: Many of the phenomena which we commonly associate exclusively with liquids and gases are manifested also by solids under the proper conditions of temperature and pressure, if time enough be given. The solid state is not a condition of total inactivity, but simply one in which change is slow—so slow that it may be overlooked. Among the phenomena

which he has shown to take place in solids are vaporization, crystallization, chemical action and the production of alloys and solutions.

Two cylinders of copper are placed base to base and held together by gentle pressure from a screw. The surfaces in contact have been most carefully polished and cleansed. They are heated to about 400° for twelve hours. This is far below the melting point of copper (1,100°). At the end of that time the union is so complete that when the mass is broken the fracture does not pass through the original junction. Cylinders of Al, Bi, Cd, Sn, Au and Pb behave in the same way, while cylinders of Sb and Pt adhere imperfectly or not at all.*

This shows that something like the liquid state occurs in metals long before they melt. The effect of pressure is similar. Powdered metals under a pressure of 10,000 atmospheres produce a mass which has all the appearance of having been fused. Rise of temperature produced by the pressure cannot be invoked to explain this fact, for it is easy to show that the elevation of temperature is very slight.

When cylinders of different metals are placed with polished surfaces in contact, and heated gently, they adhere firmly and alloys are formed at the point of junction. Thus with copper and zinc a layer of brass 18 millimeters thick is produced at the plane of contact. The following pairs behave similarly:

Cu — Cd
Cu — Sn
Cu — Bi
Fe —Zn

The time required is 4–8 hours, and the temperature, in all cases, much below the melting point of the most fusible metal present.

That copper and zinc vaporize below their melting points can be shown by making a depression in a zinc cylinder

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* *Zeit. Physikal. Chem.*, Vol. 15, p. 65.

and covering it with a copper one. When the pair is heated gently for a time, a very distinct layer of brass forms on the copper, and a brown stain containing copper on the zinc. This is not due to diffusion from the surfaces which are in contact, for when a ring of mica is placed between the two the result is the same.

When powders of different metals are compressed, alloys are formed:

Cu + Zn yield brass.
Cu + Sn yield bronze.

Mixtures of powdered sulphur or arsenic with finely divided metals yield sulphides and arsenides when powerfully compressed at ordinary temperatures. The combination of silver and sulphur is complete. Mixtures of zinc and sulphur appear to be unaffected.*

Naturally, under pressure the change takes that direction which is associated with decrease of volume. If a compound occupies more space than its constituents separately, it is decomposed by pressure. Thus the hydrate of arsenious sulphide (As_2S_3 6 H_2O) separates into water and arsenious sulphide, and the double acetate of calcium and copper yields the single acetates.† Allotropic modifications of the elements obey the same law. Prismatic sulphur passes into the denser octahedral variety, and black amorphous arsenic is converted into the steel-gray crystalline modification, which has a higher density.

Solids which are not chemically altered by pressure are not in the least decreased in volume. When the pressure is relieved the original volume is exactly restored.

Powdered chalk when compressed becomes nearly as hard as marble.‡ Some powders, however, do not appear to become compact at all under pressure. Thus Al_2O_3, Fe_2O_3 and SiO_2 do not. It is important, geologically, that such substances can usually be made to form coherent masses by compressing the *wet* powder. The explanation of this is

* *Bull. Acad. Belg.*, third series, 1883.
† *Zeit. Anorgan. Chem.*, Vol. 10, p. 185.
‡ *Zeit. Anorgan. Chem.*, Vol. 11, p. 160.

simple. A solution usually occupies a smaller bulk than the sum of the volumes of solid and liquid. Most solids dissolve with *contraction.* Hence, when a wet powder is compressed, the solution will be produced, since that will decrease the volume. Then, when pressure is relieved, some of the dissolved solid is abandoned by the liquid and deposited as a cement, which binds the grains of the powder together. On the contrary, a wet mass of potassium iodide or ammonium chloride does not at all cohere on compression since these solids dissolve with *expansion*, the volume of the solution being greater than that of solid and liquid.

From this brief résumé it is evident that Spring's work is qualitative and preliminary in character. Most of it will be gone over quantitatively, and the results expressed in tables and formulæ. But it deals with the foundations of our science, and one cannot deny to it a peculiar brilliancy of conception and execution which makes it of interest to all chemists, no matter what their special field may be, and even to educated men in general.

CENTRAL MANUAL TRAINING SCHOOL,
DEPARTMENT OF CHEMISTRY,
PHILADELPHIA, May 17, 1901.

A NEW METHOD OF TESTING THE VALUE OF LUBRICATING OILS FOR HIGH SPEED MACHINERY.

Many methods have been devised for testing lubricating oils, but those have heretofore been intended to indicate the value of the oils for journal bearings. A new device of this character has been invented by Dr. Sigmund Kapff and is described in one of the German engineering journals. It is specially adapted for the investigation of lubricants intended to be used with small bearing surfaces run at very high speed, such as spinning spindles, etc., and on a larger scale, with certain forms of high-speed wood-working machines.

The following description of the Kapff apparatus is abstracted from the *Engineering Magazine.* "The apparatus has neither belting nor gearing, the vertical spindle being driven by a small electric motor, at speeds as high as 8,000 revolutions per minute, while any desired pressure can be brought to bear upon the stop-bearing on which the spindle rests. Any desired lubricant can be used, and the work due to friction is indicated at any instant by the amount of current required by the motor. The spindle is entirely surrounded by an oil-chamber, and this in turn is enclosed in a jacketed cylinder which

prevents the escape of heat. A thermometer is inserted to indicate the temperature of the bearing for any known conditions.

"With this apparatus many properties of lubricating oils, not readily indicated by other testing devices, can be determined. Thus, many oils which show excellent results at moderate speeds, begin to work badly at 3,000 revolutions, and at higher speed. The oil seems to be entirely thrown off from the bearing, and a greatly increased frictional resistance appears. He finds, for example, as would be anticipated, that the higher speeds require oils of greater viscosity than the lower speeds; but this is found to be true within only certain limits (by taking successive mixtures of mineral oil and spindle oil, so as to obtain progressive gradations in viscosity). He shows that beyond a certain point an increase in viscosity requires an increase of work to overcome the friction.

"Proprietors of spinning mills and others employing very high speed machines would undoubtedly find it advantageous to employ some such service as this for the automatic testing of their lubricating oils." W.

THE LOSCHWITZ SUSPENSION CABLE RAILWAY.

A recent consular report gives the following interesting account of a small suspension railway lately opened for traffiic in Germany:

This new mountain railway was open to traffic May 6, and is the first of its kind for the conveyance of passengers. It runs from Loschwitz, a village on the banks of the River Elbe, about five miles from Dresden, to the top of the Rochwitz Heights, which command a most beautiful view of the Saxon capital. The railway is 820 feet long, and the grade is 32 per cent. It is constructed on the Langen system. The railways are carried by thirty-three hand-piers of varying sizes, the tallest being 49 feet high. Each car holds fifty passengers and weighs, when occupied, nearly 13 tons. Their shape and construction differ entirely from all other railway cars, even those used by the Barmen-Elberfeld Suspension Railway. The two trains of cars are connected by a steel cable 1·7 inches in diameter, and they are moved back and forth by two engines of 80 horse-power each. Safety appliances are numerous and efficient. Visible and audible signals serve to regulate the arrival and departure of the trains, and these signals are operated both from the upper and lower stations. Each car is provided with a danger signal apparatus consisting of an alarm and a telephone which enables the conductor to communicate from any part of the road with the engine house. The car is provided with three brakes, two of which work automatically at the least slackening of the tension of the cable and stop the car. An indicating device in the engine room shows at all times the exact position of the cars, and a bell warns the attendant if the train is running too fast. An automatic brake, both at the top and lower station, is put into action by the arriving car, and stops it even if the engineer is careless. A roundtrip ticket costs less than 6 cents; the journey requires only 3 minutes, and 15,550 passengers can be carried each way per day.

AN INVESTIGATION OF THE COST OF POWER.*

BY CLYDE D. GRAY.

Continued from p. 275.

THE STEAM BOILER.

Steam boilers are of many types and kinds but they may be generally divided into two great classes that are the most used in American practice: The tubular or fire-tube, in which the water is on the outside of the tubes or flues and the heated gases on the inside, and the water-tube, in which these conditions are reversed. Each of these classes has many forms, but those most commonly used are the horizontal return tubular, in which the fire is under the outside of the shell at the front end, the heated gases passing to the rear under the shell and then returning to the front through the flues and thence out of the smoke flue, and the straight inclined-tube water-tube type, in which the water is inside the tubes and the heated gases circulate around them, the Babcock & Wilcox, Heine and Root being examples of this class.

The water-tube type is being extensively used at the present time because of its greater immunity from explosion, economy of floor space, ease with which it may be cleaned and repaired, and the ability to carry the higher pressures of steam that are being demanded. The first cost of this type was formerly much higher than that of the tubular boiler; but now the cost has been reduced to such an extent, owing to increased facilities for manufacturing, that they can be purchased for nearly the same price as the other class.

The results of some boiler tests are given in the table below, showing the kind of boiler, pressure, kind of fuel used and the equivalent evaporation of water from and at 212° F. per pound combustible.

* From thesis presented for the degree of master of mechanical engineering. Sibley College, Cornell University. 1901.

WATER-TUBE BOILER TESTS.

Kind.	B. H. P.	Press. Lbs.	Water Evap.	Fuel.	Authority.
B. & W.	667	225	8·65	Anth.	Baldasano and Beach on Edison El. Ill. Co., N. Y.
"	315	225	11·32	"	
"	293	225	10·01	"	
"	362	225	10·60	"	
Worthington	143	93	11·23		Jacobus, *S. R. J.*, Jan., 1899.
"	227	96	9·87		
Campbell	110		9·18		Willis, *S.R.J.*, Dec., 1899.
Stirling	551	132	10·98		*St. Ry. Jour.*, May, 1899.
"	206	132	10·43		
B. & W.		128	8·00	(on dry bit. coal)	Buffalo Ry. Plant, 1900.
National	534	80	11·87		Whitham, A.S.M.E., 17-582.
"	902	102	11·81		
B. & W.	154	89	11·00		
"	500	102	11·38		
"	553	130	11·69	Buck'wt	
"	370	132	11·31	"	
"	581	133	11·00	"	
"	260	87	11·76	"	
"	348	85	12·19	"	
Root	168	127	10·96	"	*Sib. Jour.*, 8-341.
B. & W. (marine)		200	12·25	(nat. d. heated)	Mellville *Cass. Mg.* 15-251.
" "		200	11·02	(forced heated)	
" "		200	9·35	(forced cold)	
Root	120		12·09	Anth.	Centennial test, Kent 685.
B. & W.	136		11·82	"	
"	96		12·46	A. scr. ·2 Bit. ·8	A.S.M.E., 4-267.
"	250		9·29	Slack	
"	419		11·00	Lump	
"			11·54	Oil	14-1082.
Not given	55	89	10·61	Anth.	Barrus, "Boiler Tests."
" "	475	101	11·44	Pea	
" "	133	73	9·68	Anth.	
" "	47	104	10·00	"	
" "	244	67	10·79	Bit.	
" "	74	84	10·36	Anth.	
" "	166	62	10·93	Bit.	
" "	189	73	10·98	"	

PLAIN TUBULAR BOILER TESTS.

Kind.	B. H. P.	Press. Lbs.	Water Evap.	Fuel.	Authority.
Horizontal . . .		112	11·67		A.S.M.E., 16–49.
" . . .		74	7·54	Lump	" 16–773.
" . . .	132	102	10·26		Whitham, A.S.M.E., 17–582.
" . . .	936	97	11·14		
Return		90	9·92	(on pea coal)	Denton, A.S.M.E., 12–975.
Horizontal . . .	507	117	11·95	1 slack 2 culm	Carpenter, *Sib. J.* 7–9.
" . . .	386	105	10·50	1 slack 1 screen.	
" . . .		97	8·24	Pea	Vail, A.S.M.E., 20–157.
Vertical		112	11·36		Stone and Webster, *St. Ry. Jour.*, Aug., 1898.
Horizontal return,	79	73	10·25	Anth.	Barrus, "Boiler Tests."
" direct,	93	72	10·85	"	
" return,		116	10·55	Bit.	
" "	345	85	10·73	Anth.	
" direct,	106	70	10·73	Mixed	
" return,	68	56	10·23	"	
" "	78	63	10·74	"	
" "	135	81	9·79	Culm	
" "	129	81	9·49	"	
" "	196	63	11·33	Anth.	
" "	155	79	11·00	"	
Vertical	85	73	8·61	"	
"	94	73	10·27	Bit.	
Horizontal return,	359	83	11·11	Anth.	

MISCELLANEOUS BOILER TESTS.

Kind.	B. H. P.	Press. Lbs.	Water Evap.	Fuel.	Authority.
Portable	40	70	7·90		Webber, A.S.M.E., 13–413.
"	63	70	9·80		
Galloway			11·22		Centennial test.
Vert. fire-tube .		142	10·67		*Sibley Journal*, 9–323.
Manning, vert. .		153	10·40	(on coal)	Barrus.
Thornycroft . . .		250	11·90	" "	Mellville, *Cass. Mg.* 15–251.
Cylinder	82	97	7·97	Anth.	Barrus, "Boiler Tests."
Cast Iron Sec. . .	38	28	9·78	"	
" " " . .		82	9·26	"	
Belleville		111	10·52	Bit.	Leonard, A.S.N.E., 1890 (Kent, p. 686).
Thornycroft . . .		245		"	
Herreshoff . . .		120	10·23	Anth.	

SUMMARY OF TESTS.

Authority.	No. of Tests.	Water Evap.	Kind of Fuel.
Kent (Christie) A.S.M.E., 18–365	95	11·11	All kinds.
Barrus, horizontal tubular	16	10·76	Anthracite.
" " " low flue temp.	6	10·40	
" " " high " "	5	11·0	
" " "	10	11·59	Cumberland.
Average from above tables, W. T.	37	10·80	All kinds.
" " " " tubular	23	10·40	
Average of all the above	192	10·86	

From the above tables and summary, it is clear that the efficiencies of different kinds of boilers are nearly the same irrespective of the kind of fuel or the rate of combustion. Kent in his compilation of Christie's tests gives a table in which he shows that the evaporation is independent of the rate of combustion of the fuel per unit of grate surface. (A.S.M.E. 18–365.) Mr. LeVan in the same place says that, in his experience of about four hundred boiler trials, the efficiency has not advanced since the time of the tests made at Philadelphia in 1876. This fact is sustained by other writers also.

Mr. Barrus gives the following table showing the evaporation by different kinds of coal, taking an evaporation from and at 212° of 11 pounds of water for anthracite broken coal as the standard, rated on the combustible:

Kind of Fuel.	Equiv. Evap. Per Lb. Dry Coal.
Anthracite, broken	9·79
Cumberland, bituminous	11·04
Anthracite, chestnut	9·40
" pea	8·86
2 parts pea and dust, 1 part Cumberland	9·38
" " " " " " " culm	9·01
Nova Scotia culm	8·42

Mr. McClave, of Scranton, Pa., read a paper before the Anthracite Coal Operators' Association on January 9, 1895, in which he gave the relative values of anthracite and bituminous coals for steam raising and also the per cent. that would have to be added in weight to the different kinds to bring them up to the standard of anthracite egg.

M'CLAVE'S TABLE.

Kind of Coal.	Value. Per Cent.	Per Cent. to Add.
Bituminous coal, good quality	100	
" slack " "	90	11·1
Anthracite, steamboat, good quality	95	5·3
" broken " "	97	3·1
" egg " "	100	
" stone " "	100	
" chestnut " "	100	
" pea " " well cleaned	95	5·3
" " mixed with bone and slate	90	11·1
" buckwheat, No. 1, good quality	93	7·5
" " " 2 " "	85	17·6
" " " 3 " "	83	20·5
Anth. culm mixed with 20 per cent. soft slack, good qual.,	83	20·5
" " No. 2 " " " " " " " "	77	29·9
" " " 1 alone, good quality	75	33·3
" " " 2 " " "	70	42·9

OIL AS A FUEL.

Oil has been used to a certain extent as a fuel but its use is restricted to the locality of oil wells and even there it cannot compare in economy with coal at the average prices.

In a test by the Twin City Rapid Transit Company, of St. Paul and Minneapolis, it was found that with ordinary Lima oil weighing 6·6 pounds per gallon and costing 2.25 cents per gallon, and coal that gave an evaporation of 7·5 pounds of water per pound of coal, it cost $3.85 per ton of 2,000 pounds, including all costs of handling the oil, coal and ashes. (*Iron Age*, November 2, 1893.)

At the South Chicago Steel Works a test was made which showed that 3·22 barrels of oil equivalent to a ton of coal in steam raising and with oil at 60 cents per barrel and coal at $2.15 per ton, the relative cost of oil to coal was as 1·93 to 2·15. (A.I.M.E. 17–817.)

The evaporative power of oil given by Pike and Hugo, as the results of tests, was 11·54 pounds of water per pound oil at St. Paul and 11·87 at Minneapolis. (A.S.M.E. 14–1082.)

Mr. Barrus, in his book on boiler tests gives, in one case, an evaporation of 11·96 pounds of water, another of 13·66 pounds with petroleum residue, and one of 15 pounds with Canada oil. He says that the cost of oil must be less than $1 per barrel to compete with Cumberland coal.

ENGINE TESTS.

SIMPLE AUTOMATIC, NON-CONDENSING.

Kind or Use.	Press.	I. H. P.	Steam Per H. P.	Authority.
	90	26	25·0	Hirn, A.I.E.E., 10–287.
	87	76	30·9	Carpenter, " "
Electric power . . .		88	34·6	Hensen & Riker, *Sib. Jour.* 11–97.
Schmidt	127	23	14·8	Thurston, A.S.M.E., 18–820.
		21	44·1	Carpenter, A.S.M.E., 14–426.
		83	33·6	
		76	31·0	
		455	30·9	11–723.
	82		30·6	Barrus, A.S.M.E., 9–545.
	77		29·0	
	90		29·3	
	72		27·8	
	100		25·8	
Semi-port	61	5	65·0	Unwin, *Cass. Mag.*, 5–353.
Small		13	41·0	
"	35	6	44·0	Donkin, *Cass. Mag.*, 5–353.
Willans	44	9	41·8	Willans, *Cass. Mag.*, 5–353.
" slow . . .	112	20	30·2	
" fast	36	16	42·8	
" "	74	26	32·6	
" "	122	34	26·0	
Mill	76	310	25·6	Barrus, "Engine Tests."
Electric light . . .	103	53	32·7	
" " . . .	105	27	34·0	
Test	92	45	32·6	
Cotton mill	68	209	28.6	
Factory	65	32	40·0	
Woolen mill	80	62	32.7	
Shop	74	71	29·4	
	72	38	37·2	
Average			33·4	

SIMPLE CORLISS, NON-CONDENSING.

	90		29·3	Barrus, A.S.M.E., 11–153.
	68		34·0	
Reynolds	97	137	23·9	Hill, *Cassier's Mag.*, 5–353.
Harris	96	134	22·0	
Wheelock	96	140	24·9	
Mill	72	305	27·8	Barrus, "Engine Tests."
"	101	506	25·8	
"	99	342	25·9	
"	81	232	29·0	
Average			28·9	

COMPOUND AUTOMATIC, NON-CONDENSING.

Kind or Use.	Press.	I. H. P.	Steam.	Authority.
Shop test	100	56	22·1	Thurston, A.S.M.E., 18–988.
" "	100	55	25·7	
	90	64	26·2	16–838.
		114	23·8	Carpenter, A.S.M.E., 14–426.
		111	23·1	
Shop test			25·4	Bole, A.S.M.E., 12–275.
Service test			22·4	
		70	32·8	Carpenter, A.S.M.E., 11–723.
Willans, slow	89	10	27·0	Willans, *Cassier's Mag.*, 5–353.
" "	103	11	24·7	
" "	120	13	23·4	
" fast	114	33	21·4	
" "	135	36	20·4	
" "	165	40	19·2	
Buckeye	125	180	20·4	Mansfield, A.S.M.E., 20–243.
Electric light	128	231	22·5	Barrus, "Engine Tests."
" "	128	153	25·2	
" "	136	110	22·9	
	118	267	23·2	
	129	347	22·1	
Dynamo	165	243	21·3	
Average			23·6	

SIMPLE AUTOMATIC, CONDENSING.

Kind, Use.	Press.	Vac.	I. H. P.	Steam.	Authority.
Mill	79	23·6	336	20·5	Barrus, "Engine Tests."
Cotton mill,	67	25·5	213	22·1	
" "	75	24·8	205	27·2	
Factory	68	23·0	444	23·0	
Mill	82	27·9	613	18·5	
El. light	83	26·7	206	21·4	
Average				22·2	

SIMPLE CORLISS, CONDENSING.

		62	28·7	Carpenter, A.S.M.E., 11–723.
	66		19·9	Barrus, A.S.M.E., 11–153.
	50		24·3	
	85		19·2	
	83		18·5	
Corliss	61		19·3	Langridge, *Cass. Mag.*, 5–353.
Harris	96	166	19·4	Hill, *Cass. Mag.*, 5–353.
Reynolds	96	163	19·5	
Wheelock	96	158	19·3	
Sulzer	75	395	19·7	Linde, *Cass. Mag.*, 5–353.
"	87	284	18·4	
"	90		19·0	Linde, *Eng. Mag.*, 10–853.

Kind, Use.	Press.	Vac.	I. H. P.	Steam.	Authority.
Corliss . .	62		137	17·5	Thurston, *E. W.*, Jan. 5, 1901.
Mill . . .	70	24·2	554	19·5	Barrus, "Engine Tests."
Factory . .	67	26·2	211	21·1	
Mill . . .	68	29·8	362	18·7	
" . . .	71	26·7	758	18·3	
" . . .	70	21·0	258	23·6	
Average				20·2	

COMPOUND AUTOMATIC, CONDENSING.

Marine . .	110		534	17·9	A.I.E.E., 10–287.
" . .	115		132		Stebbins, *Sibley Jour.*, 9–341.
El. Railway	127			21·7	Manning, " " 9–370.
" "	124			22·5	
Schmidt .	165		112	10·6	Thurston, A.S.M.E., 18–820.
" .	159		70	9·6	" " "
	90		64	26·2	" " 15–838.
Shop test .	100		56	17·5	" " 18–988.
" " .	100		55	20·6	" " "
El. Railway			523	29·3	Pike & Hugo, A.S.M.E., 14–1,082.
" "	118		783	23·5	
			89	19·2	Carpenter, " 14–426.
			95	19·1	
	130		95	18·8	11–723.
Portable .	101		6	35·7	Unwin, *Cass. Mag.*, 5–353.
Marine . .			371	21·2	Kennedy, " " "
Marine . .	165		1979	21·7	
El. light .	129	25·0	228	18·9	Barrus, "Engine Tests."
" " .	105	28·0	149	22·0	
" " .	121	27·0	221	18·0	
Cent. pump	126	21·1	348	18·2	
El. light .	130	25·5	197	19·1	
" " .	120	25·1	296	16·1	
Willans . .	165			14·3	Willans, *Eng. Mag.*, 10–853.
Average				19·8	

COMPOUND CORLISS, CONDENSING.

Railway .	112		709	15·1	Stone & Webster, *S. R. J.*, Aug.,'98.
" .	110	26·0	469	14·3	Willis, A.I.E.E., 1899.
" .	150		600	14·5	*Cassier's Mag.*, Feb., 1901.
" .	112	26·5	373	13·8	Willis, A.I.E.E., 1899.
" .			200	17·6	*Cassier's Mag.*, Feb., 1901.
" .	115		400	23·0	*Sibley Journal*, 11–93.
" .	105		483	23·2	" " 8–393.
Mill . . .	117		1,001	16·3	" " " (R.C.C.).
Railway .	81		80	27·3	" " "
	155		1,950	12·5	Thurston, *Science*, Oct. 1, 1897.
El. light .	109	25·0	189	20·5	Christie, A.S.M.E., 19–301.
Cotton mill	123	27·1	1,076	12·8	Dean " "

Kind, Use.	Press.	Vac.	I. H. P.	Steam.	Authority.
Sibley . .	115	22·8	129	15·8	Thurston, A.S.M.E., 19–152.
El. light .	90		137	20·9	" " 15–838.
Mill . . .	100		999	21·1	" " "
" . . .	100			13·3	" " "
Wheelock .	145			13·1	Denton, " 14–1,340.
Mill . . .	151		997	12·8	Barrus, " "
	123	25·6	1,592	13·5	Thurston, " 15–839.
	120		1,018	13·3	Barrus, " "
Railway .	112		70	24·6	
Mill . . .	159	25·4	595	12·7	Dean, " 16–169.
				16·6	Carpenter, " 11–723.
Wetherill .				16·3	Main, A.S.M.E., 10–48.
Sulzer . .				14·1	
" . .				13·7	
				15·8	
				18·9	
Mill . . .	53		57	20·5	Donkin, *Cass. Mag.*, 5–393.
" . . .	87		888	17·8	Longridge, " " "
" . . .	87		862	19·8	
" . . .	95		314	17·0	
" . . .	95		338	17·2	
Sulzer . .	90		267	14·0	Sulzer, " " "
	90		135	15·3	Uincotte, " " "
	110		272	15·3	Soldini, " " "
Dujardin .	90		548	13·5	Thurston, *E. W.*, Jan. 5, 1901.
Sulzer . .	85		247	13·4	
Wheelock .	160		590	12·8	
Railway .	130	26·2	534	16·1	*St. Ry. Journal*, May, 1899.
Mill . . .	147	27·1	524	14·5	Longridge, *Mech. Mag.*, October 13–1899.
" . . .	148	27·2	521	13·9	
Cotton mill	95	27·2	607	16 3	Barrus, "Engine Tests."
" "	116	25·5	637	13·3	
El. light .	127	27·4	384	14·1	
Factory . .	108	27·0	280	13·4	
Cotton mill	151	27·0	689	12·7	
" "	126	27·0	1,107	14·1	
" "	115	28·4	873	14·2	
" "	108	27·2	798	13·3	
" "	150	26·9	1,713	12·3	
" "	144	25·2	741	13·2	
Factory . .	115	25·6	300	15·8	
El. light .	151	26·8	1,713	13·3	
" " .	108	25·2	676	14·6	
Cotton mill	133	25·2	1,539	14·1	
Dynamo .	136	26·2	1,030	13·2	
Average				15.74	

TRIPLE CORLISS, CONDENSING.

Kind, Use.	Press.	Vac.	I. H. P.	Steam.	Authority.
	141		125	13·7	Peabody, A.I.E.E., 10-279.
El. light .	142		475	15·3	*Sibley Journal*, 9–323.
Sibley . .	119	24·3	113	13·7	Thurston, A.S.M.E., 19–152.
Mill . . .	150	26·9	671	12·4	Barrus, " "
El. light .	160			15·0	Report of N.E.L.A. for 1897.
Mass. Tech.	143	25·0	102	15·0	*Trans.*, A.S.M.E., 16–89.
" "	145	26·2	102	13·3	
Augsburg .	88			13·4	Schröter, " "
Wheelock .	140			13·0	Denton, " 14–1,340.
Boston Ry.,	158		973	12·3	Mann & Larkins, "
Mass. Tech.	90		150	16·3	Table in *Trans.* A.S.M.E., 15–838.
" "	88			14·7	
	156		200	12·7	Schröter, " "
Sulzer . .	150		1,200	11·7	
" . .	155	27·0	1,870	11·3	Hill, A.S.M.E., 18–795.
" . .	168		631	10·8	
" . .	168		735	10·7	
	145		200	12·6	Jacobus, " 11–275.
El. light .	125	26·5	532	12·9	Henthorn, " 11–643.
				18·6	Carpenter, " 11–723.
Willans . .	172		39	18·5	Willans, *Cass. Mag.*, 5–353.
Sulzer . .	145		360	11·7	Sulzer, " " "
" . .	156		198	12·2	Schröter, " " "
Augsburg .	145		700	12·5	
Marine . .	145		1,994	15·0	Kennedy, " " "
" . .	144		1,087	19·8	
" . .	165			13·3	" " *Eng. Mag.*, 10–853.
	192			12·7	Reynolds, " " " "
Willans . .	175			12·7	Willans, " " " "
Sulzer . .	141		615	11·9	
Reynolds .	120		574	11·7	Thurston, *Elec. W.*, Jan. 5, 1901.
Leavitt . .	185		576	11·2	
Snow . . .	156		773	11·3	
Ringhoffer,			805	10·9	*London Eng.*, Mar. 8, 1901.
"			653	10·6	
Cotton mill	151	27·0	997	12·7	Barrus, "Engine Tests."

Average . . . . . 13·3

QUADRUPLE, CONDENSING.

Hall-Treat.	300		16	10·8	
"	400		16	9·7	Thurston, *Elec. W.*, Jan. 5, 1901.
"	500		16	9·8	

STEAM TURBINES.

Kind.	Press.	Vac.	D. H. P.	Steam.	Authority.
Laval . . .	100			21·3	Ewing.
" . . .	130		11	47·8	Goss, A.S.M.E., 17–83.
" . . .	115	26·0	64	19·7	Cederblom, A.S.M.E., 17–83.
W'stingh'se	125	26·5	400	12·2	*Elec. World.*, Jan. 5, 1901.
Parsons . .	162		1,330	15·0	*Sci. Am.*, Jan. 12, 1901.
" . .	130		1,610	14·0	*Elec. World*, Jan. 5, 1901.
Laval . . .			300	15·8	*Sci. Am.*, Jan. 12, 1901.
Dow . . .				45·0	
Curtis . .	130	28·0		25·0	
Parsons . .	127	24·8	800	16·7	Baker, *Elec. World*, p. 313, 1900.
" . .	139	24·5	705	18·0	
Laval . . .		145	26·0	19·3	Edison El. Ill. Co., 1896.
Parsons . .		0·		30·9	*Lond. El. Review*, Feb. 19, 1897.
" . .		Cond.		19·5	

PUMPING ENGINES.

SIMPLE.

Kind, Place.	Pressure.	I. H. P.	Steam.	Duty in Millions.	Authority.
Lawrence . . .			16·5	112	
Beam	45	120	21·3		Mair, *Cassier's Mag.* 5–353.
"	42	123	22·0		Longridge, " "
Average			19·9		

COMPOUND.

Wolff	106		12·7		Denton, A.S.M.E.,	14–1340.
	125	313	13·5		Jacobus, "	"
Louisville . .	137	643	12·2	138	Dean, "	16–169.
Worthington .	88	443	17·0	109	Denton, "	12–975.
Pawtucket . .	125		13·6		" "	11–328.
	94	607	16·3		Barrus, "	9–545.
	100		14·7		Coon, "	"
	70	177	20·9		Mair, *Cassier's Mag.*, 5–393.	
	61	127	14·8			
Worthington .	75	296	17·4			
	60	255	17·7			
Beam	99	252	13·9		Leavitt, " "	"
"	99	290	14·2			
Average			15·3			

TRIPLE.

Kind, Place.	Pressure.	I. H. P.	Steam.	Duty. Lbs. Coal Per I. H. P.	Authority.
Worthington	150	294	14·4		*Power*, November, 1900.
Boston	186	801	14·5	157	*London Eng.*, Sept. 2, 1900.
	126	574	12·6		Barrus, "Engine Tests."
	151		13·4	125	Denton, A.S.M.E., 14–1,340.
Milwaukee	121	573	11·7	138	Carpenter, " "
Chicago	120	1,092	12·0	135	Hunt, " "
Trenton	112	235	13·4	118	*Transactions*, A.S.M.E., 16–49.
Allegheny	180	294	13·8	129	
Detroit		574	12·5	130	*Journal* A.E.S., July, 1900.
St. Louis		813	10·8	155	
"		802	10·7	159	
Chestnut Hill		576	11·2	142	
Buffalo		1,185	12·4	135	
Indianapolis		776	11·3	150	
Average				12·3	

QUADRUPLE.

Nordberg	200	712	12·3	163	Carpenter, *Sib. Jour.*, 13–76.

SUMMARY OF ENGINE TESTS.

SIMPLE, NON-CONDENSING.

Authority.	Aut.	Corliss.
Carpenter (Sibley theses, *Sib. Jour.*, 14-228)	34·3	28·3
L. Bell, "Electrical Transmission of Power"	33·0	28·0
Hutton, "Mechanical Engineering of Power-plants"	33·0	29·0
Thurston & Carpenter, A.I.E.E., 10–297	31·5	28·6
Davis, C. H., *Engineering Magazine*, 12–942.	36·0	31·5
Average of my tables	33·4	28·9
Average of all above	33·8	29·0

COMPOUND, NON-CONDENSING.

Carpenter	32·3	
Bell	24·0	22·0
Hutton	26·0	24·0
Thurston & Carpenter	24·5	
Davis	27·0	26·0
Tables	23·6	
Average	26·2	24·0

SIMPLE, CONDENSING.

Carpenter		
Bell	25·0	21·0

Authority.	Aut.	Corliss.
Hutton	22·0	20·0
Thurston & Carpenter		23·0
Thurston, *Engineering Magazine*, 7-844		25·0
Davis	31·0	26·5
Tables	22·2	20·2
Average	23·1	22·6
COMPOUND, CONDENSING.		
Carpenter	22 7	18·3
Bell	20·8	18·0
Hutton	20·0	18·0
Thurston & Carpenter	18·8	17·2
Davis	22·5	23·0
Thurston		18·0
Tables	19·8	15·7
Average	20·6	17·7
TRIPLE, CONDENSING.		
Carpenter		
Bell	17·0	13·0
Hutton	17·0	16·0
Thurston & Carpenter		14·6
Thurston		14·0
Tables		13·3
Average	17·0	14·2

PUMPING ENGINES.

	Simple.	Compound.	Triple.	Quadruple.
Average of tables	19·9	15·3	12·3	12·3

The above are all condensing and are generally for the larger sizes of pumping engines.

The above summary serves to show the results obtained from my collection of tests and compares them with tables of average performance as given by other authorities. It may be seen that they check fairly well with the other tables.

STEAM PLANT COSTS.

The cost of steam plants vary greatly with the locality, size, kind of machinery, boilers and many other items. The table given below may serve to show what such costs have been in the past as recorded in the different engineering literature. It may be considered to be a very good approximation to the actual cost of such construction.

TABLE OF PLANT COSTS.

Authority.	Cost Per H. P.	Remarks.
Manning, A.S.M.E., 10–48 . .	68·26	Total, engine, boilers, stack, 500 horse-power plant.
" " " . .	52·50	Same, 1,000 horse-power plant.
Field, C. J., " 16–504 . .	50·00	Steam plant complete.
Webber " 17–41 . .	65·00	Plant complete.
" " " . .	54·71	High speed condensed, from Emery's tables for 550.
" " " . .	59·51	Low speed from Emery.
" " " . .	60·35	Comp. low, " "
" " " . .	70·00	Triple comp., " "
Dean, " 19–301 . .	70·00	Simple Corliss cond., best, 1,000 h. p.
" " " . .	57·00	Comp. cond., best, 1,000.
" " " . .	60·50	Actual cost of a yarn mill, 1,132 h. p.
Rathwell, A.I.M.E., 17–555 . .	40·00	Engines and boilers.
Western Elec., Mar. 16, 1901 .	60·00	Complete plant.
Carpenter, *Sib. Jour.*, 14–298 .	28·60	Simple slide-valve, non-condensing.*
" " " " .	30·20	Corliss, non-condensing.
" " " " .	30·00	Comp, slide-valve, non-condensing.
" " " " .	30·00	Non-condensing cond.
" " " " .	33·25	Comp. Corliss, cond.
Elec. World, Feb. 2, 1901, 214 .	28·50	Estimates on plant for South Africa.
Thurston, *Eng. Mag.*, 7–844 .	38·00	Engines, boilers and piping, simple cond.
" " " " .	45·00	Compound cond.
" " " " .	53·00	Triple cond.
" " " " .	62·00	Quadruple cond.

Field in A.S.M.E. 16–504, gives the average cost of steam plants as ranging from $50 to $55 per horse-power and Professor Ryan in an article in the *Engineering Magazine*, 7–733, says that the cost of steam plants with high speed engines is about $50 and that for slow speed Corliss engines ranges from $65 to $75. This is exclusive of the cost of the buildings.

The costs of electric plants are dependent upon the cost of engines and boilers and their cost is usually a constant quantity, for the cost of dynamos is nearly constant per kilowatt plus the cost of engine plant. The cost of dynamos and other electrical apparatus may be assumed as ranging from $20 to $35, including switchboard. Hence the cost of complete plants for electric lighting and power may be

* The costs under this are for engines, boilers and piping alone, exclusive of cost of building.

assumed to cost from $75 to $100, dependent upon circumstances.

COST OF STEAM POWER.

The cost of generating steam power is extremely variable and depends upon many factors among which may be mentioned, the kind and steadiness of load, the hours of service per day, the kind of engines, quality of fuel, efficiency of boilers and engines.

A few figures relating to the cost of steam power are given in the table below. These are taken from different sources and show the cost under various conditions.

TABLE.

Authority.		Fixed Cents.	Operating.	Total.	Time.
Emery, A.I.E.E., 12–358		0 09	0 23	0 31	Continuous.
Gerry, " 14–353				37	Ry. plant.
Foster, A.I.E.E., 14–385	S-S-N	38	1 52	1 90	6 cases.
	S-H-N	44	2 44	2 88	4 "
	S-S-C	11	78	90	1 "
	Pump	74	1 18	1 92	3 "
	C-S-C	25	57	82	4 "
	T-S-C	19	32	51	1 "
	S-H-N	12	85	97	From Emery's table.
	S-S-N	12	74	86	
	C-H-N	11	70	81	
	T-H-N	11	65	77	
	S-H-C	16	61	77	
	S-S-C	11	55	66	
	C-H-C	10	57	67	
	C-S-C	11	51	62	
	T-H-C	10	51	61	
	T-S-C	12	47	59	
	"	13	45	58	
		21	43	64	Webber, yarn mill.
		22	51	73	
		21	35	56	Hale, yarn.
		17	54	71	May, pump.
	Compound	20	44	64	Main, 3,157 hours per year.
	Condensing	20	55	75	
	High-pressure	21	63	83	
Elec. World, Dg. Eng. Mag., Feb., '00				90	In Italy.
C. J. Field, *Cass. Mag.*, Mar., 1896				92	Triple cond.
Sci. Am., Oct. 6, 1900	Oil fuel			2 90	Non-cond.
	" "			2 40	Condensing.
Main, A.S.M.E., 13–140		26	42	68	500 h. p.

Authority.		Total.	Time.
Brown, *West. Elec.*, Feb. 23, 1901		0 50	3,080 hours.
		32	
May, A.S.M.E., 15–1,147	Manning's data	58	Continuous.
	Main's "	59	
	Milwaukee pump	63	6,980 hours.
	Triple pump	63	Continuous.
	Same	1 04	3,180 hours.
	Comp. mill	53	Continuous.
	Same	79	3,180 hours.
	Electric light compound	1 59	Continuous.
	Same	2 64	3,180 hours.
	Electric railway compound,	66	Continuous.
	Same	1 00	3,180 hours.
	Triple, electric railway	62	Continuous.
	Same	91	3,180 hours.
	Non-condensing	87	Continuous.
	Same	1 67	3,180 hours.
Average of all above		95	
" neglecting those over 1.0 cent		72	

The tables given by Foster are perhaps the most reliable of the recent data on the subject. In these tables, he has worked out the costs for a year of 7,300 hours from the data and estimates of Dr. Emery given in *Trans. A.I.E.E.*, March, 1893. His own figures are from actual cases. The letters used to denote the different kinds of engines are to be read thus: *e. g.*, S-S-N. Simple, slow speed, non-condensing. H is for high speed, C for compound and condensing and T for triple engines.

Mr. Foster gives a very interesting table of the cost per horse-power hour of power generated by large compound condensing engines as estimated by different authorities. This table is given below as well as the average of my table.

Authority.	Cost Per H. P. Hour Cents.
Emery, A.I.E.E., for 3,080 hours per annum	0.784
" " " 7,090 " " "	.617
" *Eng. Mag.*, " 3,080 " " "	.856
Webber, 650 h. p., " " " " "	.720
" 1,050 " " " " " "	.646
Hale, " 2,985 " " "	.557
Main, " 3,080 " " "	.637
Foster, " " " " "	.824
My table	.720
Average of all	.707

Mr. Louis Bell in his book, "Electrical Transmission of Power," gives as the cost for 10-hour day, full load with large compound condensing engines, ·8 to 1·0 cents per horse-power hour and for simple engines, 1·5 to 2·5, while if the load is partial and intermittent, these figures become 1·0 to 1·5 3·0 to 4·0 respectively.

The cost of engines varies considerably with the class, but the following table is a very good approximation for the different kinds:

Simple slide valve engine	$7 to $10
" Corliss or low speed type	11 " 13
Compound slide valve	12 " 15
" Corliss	18 " 23
High speed automatic	10 " 13
Low " "	15 " 17

In addition to this is the price of boilers which is approximately $10 to $12 for the plain tubular and about $15 for the water-tube type and the cost of pumps which is about $2 for a non-condensing and $4 for a condensing plant, including heaters.

The costs given are often modified greatly for specific cases depending upon the amount of competition for the contract and other variables of a like nature, so that it is difficult to give more than approximate prices on anything of this kind.

GAS ENGINES.

The gas engine is coming into use at the present time as a rival of the steam engine, especially in the smaller sizes and for such purposes where an intermittent source of power is required, for there is no loss while the engine is standing idle as there is in the case of the steam engine. The great disadvantages of the gas engine are being overcome to-day, so that it will do the work of the steam engine in almost all cases. The regulation was the great drawback to the general adoption of the gas engine, especially for electrical work, the old single cylinder, four cycle, hit-and-miss ignition not being good for such use; but now, with the adoption of the electrical ignition and throttling

governor, together with the employment of more than one cylinder, so that there is an explosion oftener than once in every two revolutions, the gas engine is a serious rival of the steam engine in many cases.

The advantages of the gas engine are: Small amount of space required for a given output; ease of managing, cleanliness; a cheaper grade of coal may be used for fuel in the gas producer than in the boiler and more of the heat utilized; no expense while engine not running; the thermo-dynamic efficiency is much higher than that of the steam engine; it may be run on waste gases from blast furnaces, thus making the item for fuel a nominal one, and, in regions where natural gas is obtainable, it is much cheaper than the steam engine.

Some of the disadvantages are: The liability of its getting out of repair or adjustment, so that it is not as reliable for general rough usage as the steam engine. The greater cost per horse-power sometimes stands in the way of its installation—where steam has to be generated for other purposes than power, of course it cannot compete with the steam engine—it cannot be made in very large units, although engines up to 1,000 horse-power are common; it does not regulate quite closely enough for the operation of alternators in parallel, which is a common requirement at the present time; and, lastly, there is a prejudice against its use that is hard to overcome.

It seems fitting to begin the discussion of the gas engine with some values of the different kinds of gas that are used. There are several kinds of gas that are good for this purpose, natural gas being the best as it has the highest heating value per unit volume. Next comes the ordinary coal gas, such as is made for commercial lighting. Then water gas and producer gas which are made from coal, water and air being passed through the furnace while the coal is burning, in small amounts, and, lastly, waste gas from blast furnaces, which is very low in heating value, so that special engines are needed to use it. The latter gas is being used more in Europe than in this country, but it will come more and more into use as other fuel becomes more expensive.

NATURAL GAS VALUES.

Locality.	B. T. U. Per Cubic Foot.	Authority.
Indiana, average of all	1,023	H. Poole, "Calorific Power of Fuels."
Ohio, " " "	1,030	
Average of all American	975	
American	1,000	Reichelm in "Kent's Handbook."
Burn's Well, Pa.	1,151	McGruder, *Power*, Feb., 1901.
4 Indiana, 3 Ohio, average	1,103	Webster, *Cass. Mag.*, 13–293.
American	1,000	Kerr, " " 18–425.
"	1,100	Taylor, A.I.M.E., 18–859.
Leechburg, Pa.	1,051	Robert's "Gas-engine Handbook."
Pittsburg, Pa.	892	
Average of all	1,033	

COAL GAS.

Strengtn.		
20 candle-power	675	Reichelm, "Kent's Handbook."
	675	*Elect. Eng.*, Jan. 25, 1901.
15 " "	620	*Power*, Feb., 1900.
Ordinary	550	Donkin, *Eng. Mag.*, Dec., 1900.
"	735	Webster, *Cass. Mag.*, 13–293.
"	735	Taylor, A.I.M.E., 18–293.
28 candle-power	950	Robert's, "Gas-engine Handbook."
19 " "	800	
15 " "	620	
Average of all	706	

WATER GAS.

Kind, Composition.	B. T. U. Per Cubic Foot.	Authority.
From coke	313	Reichelm.
" bituminous coal	377	
Lowe process, H-35 : CO-25 : CH-19	740	Poole, "Calorific Power of Fuel."
" " " 42 " 35 " 12	490	Power carburetted.
" " " 38 " 31 " 17	590	
Granger " " 53 " 36 " 2	283	" uncarburetted.
" " " 30 " 29 " 24	640	" carburetted.
" " " 52 " 12 " 8	331	" from coke.
New York, carburetted	721	Lowe (Kent).
Uncarburetted	322	Webster, *Cass. Mag.*, 13–293.
Carburetted	700	
" H-30 : CO-29 : CH-24	641	Jacobus, A.I.M.E., 17–300.
Uncarburetted	283	
"	322	Taylor, " 18–859.
New York, carburetted	711	Roberts.
Average of the carburetted	651	
" " " uncarburetted	319	

The carburetted gas has oil mixed with it so that it can be used for illuminating purposes, otherwise the flame is not luminous enough unless it is used in Welsbach burners. The heating value is also almost doubled and the additional expense is merely nominal, apart from the cost of the oil used.

[*To be concluded.*]

A NOTABLE BALLOON VOYAGE.

Messrs. Berson and Suehring, the famous meteorological aëronauts of the Berlin Observatory, according to the *Scientific American*, accomplished a magnificent ballooning feat recently by attaining an altitude of 33,800 feet—almost six and one-half miles. This is the greatest height recorded by the instruments carried by the aëronauts, but it is probable that they ascended to a greater altitude. The maximum height they attained, however, is unknown, since both the observers fainted owing to the rarefied atmosphere. The temperature last observed by them was 40° of cold. Herr Berson ascended to 27,000 feet at the Crystal Palace a few years ago. The latest achievement is certainly notable in the annals of aëronautics, but it is not the highest altitude that has been attained by a balloonist. In September, 1862, Messrs. Glaisher and Coxwell ascended from Wolverhampton to a height of 36,000 or 37,000 feet. The exact altitude was not recorded, since the two men were overcome by the intense cold, and the rarefaction of the atmosphere. Mr. Glaisher fainted and Mr. Coxwell only just succeeded in opening the valve by pulling the valve-rope of the balloon with his teeth to enable the vessel to descend.

POTASSIUM SALTS FROM FELDSPAR.

Scientific American gives the following abstract of a process devised by Mr. J. G. Rhodin, of Manchester, England, of manufacturing potassium salts from feldspar. The feldspar is primarily finely ground, and is then mixed with slaked lime and sodium chloride, the mixture being subsequently heated to 900° C. By this means about 85 per cent. of the potassium in the feldspar is extracted in the form of potassium chloride. It is stated that the process is very cheap and is well adapted for commercial purposes. It is proposed to carry out a series of further experiments with the process prior to erecting a factory in Sweden for the manufacture of potassium salts upon an extensive scale. The latter country is peculiarly adapted as the center of such an industry owing to the abundance of feldspar which is to be found there, and for which so far there has been no commercial utility. Another prominent feature of the process is that the insoluble residue that remains after the potassium and sodium salts have been extracted by water constitutes an excellent material for glass manufacture by the addition of a little sand and alkali.

Section of Photography and Microscopy.

Stated Meeting, held Thursday, October 3, 1901.

APPLICATION OF PHOTOGRAPHY TO LEGAL RECORDS.

By Henry Leffmann.
Member of the Section.

The transfer of real estate under which term (disregarding legal hair-splitting) we may understand land and the buildings thereon, has always been a matter of some difficulty and complexity. In many times and places land was and is practically inalienable. Even now, in the most enlightened nations, the legal fiction is that all land belongs to the supreme authority, that is, the crown in such a country as England, and the State in such a country as our own. Upon this principle rests the right of eminent domain which the State sometimes exercises in its own interests and sometimes confers upon corporations. Land being irremovable, the occupancy of it is not evidence of ownership, and it is impossible to conceal its existence. As it is the only natural monopoly it is the foundation of all wealth in the strict sense of that word. If we carefully analyze the transactions of both nations and individuals, we will find that a common impulse of humanity is that of land-grabbing, whether it be the conquests of a Joshua or Cæsar, or the "benevolent assimilations" of our own age and country.

The enlightened nations of the present day differ considerably as to the amount of land transfer and the methods of it. We are so accustomed in this country, and especially in this city, to the public record of deeds, mortgages and judgments and to the publication of names of sellers and buyers, and even of delinquents, that we are surprised to learn that this is not by any means universal, and in some places quite against the will of the community. Some

notable contrasts are to be found also among what are considered happy countries, in regard to the distribution of land ownership. Thus it is stated on good authority that the average number of land transfers annually in France is about 800,000, while the total number of land owners in England is only about 200,000, so that for England to have as much conveyancing business as France would require that each English owner should make transfers four times each year.

In Philadelphia the exact extent of the business is not easily obtainable, but by inquiry at the office of the Recorder of Deeds I learn that in the record work about 400 books are filled each year, each book containing 560 pages of the size of the large counting-house ledgers. This will make nearly 250,000 pages per year. These books contain principally deeds and mortgages, about equal number of each; releases, powers of attorney and some other documents affecting property make up the remainder. To make these copies, which are expected to be word for word, a large force of transcribing clerks is maintained.

Mr. J. W. Ridpath kindly ascertained for me the statistics of two of the adjoining counties for 1900, as follows:

Montgomery County, 5,548 documents, 12,000 to 14,000 pages.

Bucks County, 2,684 documents, 5,210 pages.

Another very important record department is that of the Register of Wills. In this city, and I believe, generally, it is the rule to preserve the original document and furnish to interested parties a certified copy. The original may be seen by any one. These methods are obviously open to the same objections that apply to the transcription of deeds and mortgages, with the additional one that as the original is open to inspection it may be liable to injury. The number of wills registered in Philadelphia in a year is considerable. A lawyer of this city told me that a will was filed not long ago in a city of western Pennsylvania, of which three official copies were furnished by the register's office, and all the copies differed, although all were duly certified as exact.

It must be apparent to every one that transcriptions by hand are at best clumsy. The Philadelphia departments are in good repute with attorneys, but even under the most favorable circumstances there is considerable delay in the recording of an instrument. This does not operate to the disadvantage of parties, since the instrument takes effect at the moment it is presented for record. The possibilities of error in transcription must always be in mind, although here, again, there is less risk, because the original document is returned to its owner and this document is, of course, always the best evidence.

Some countries have adopted a plan by which the original document is deposited at the registry office; but this method is in vogue to only a limited extent, and even it is not free from objection.

When the systems of transcription were inaugurated, the possibilities of photography were not only unknown, but were quite unsuspected. At the present day the art of duplication of writing or drawing has been brought to high degree of perfection. Several methods are known by which such reproduction can be accomplished rapidly, accurately, and cheaply. Nor is the work confined to the copying of well-made originals consisting of black lines on a white ground; even old yellow manuscripts on parchment can be reproduced with vividness not appreciably inferior to the originals. As some of those present will remember, I exhibited at a former meeting a fine sample of this class. Lead-pencil writing on common white paper can be well reproduced.

Briefly, I propose that for all documents which are to be copied for record a negative shall be made either of full size or somewhat reduced, if thought permissible, and from the negative prints shall be made by the best processes. The negatives are not to be kept, hence the same glass can be used a number of times. The paper must be of the best quality, especially as to its resistance to decay. There is nothing in the problem that is uncertain or indefinite. Photography of this character can be carried out independently of the weather or time of day; permanent pictures

can be made and control can be exercised over the work at all points. With regard to wills, I propose that even if it be thought necessary to keep the original document the public should be allowed access only to the photographic copies, which should be bound in indexed volumes. To facilitate the work some method of drawing up legal documents may be laid down, such as standard size of sheet, character of ink, and other details; but I am informed by an attorney that recording officers would, under present laws and customs, probably be obliged to accept for record any legible document, so that very close requirements would probably be impracticable at first, and as far as wills are concerned, of course impossible. However, whatever the eyes can read, the camera can also read, and there will be no practical difficulty on this point.

Mr. Getty, of the International Engraving Company, has kindly made a full-size copy from a mortgage loaned me by an attorney of this city. The original is about thirteen years old, and hence presents some greater difficulty than a fresh document; but, as will be seen, the result leaves nothing to be desired. In fact, the attorney who loaned the document mistook the copy for the original.

NEW YORK RAPID-TRANSIT SUBWAY.

Work is progressing on the great rapid-transit subway in New York at a most satisfactory rate. Despite the great obstacles presented by the extremely difficult character of the excavation, the street traffic, which must be interrupted as little as possible, and the presence of a multitude of large and small street pipes in the exact route to be traversed, the work of building the tunnel is being prosecuted with a speed hardly to be expected. In the meantime a site for the great power house has been selected and contracts have been closed for boilers, engines and electrical generating apparatus. The electrical part of the power-house equipment was ordered only a few days ago. New York hesitated a long time before deciding to go in for a rapid-transit subway; the project dragged along for years with all sorts of changes in the laws and commissions having to do with the subject; but since the final adoption of the plans and the awarding of the blanket contract, the work has been pushed with a vim and energy that is most commendable.—*Western Electrician.*

GENERAL ELECTRIC COMPANY'S CONSTANT CURRENT TRANSFORMER FOR ALTERNATING SERIES ARC LIGHTING.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Prof. Elihu Thomson. Sub-Committee: Francis Head, Chairman; Geo. A. Hoadley, T. C. Smith, Thos. Spencer.*]

HALL OF THE FRANKLIN INSTITUTE,

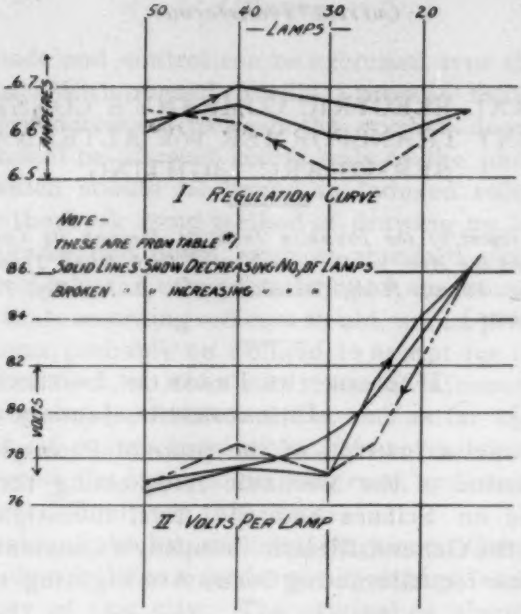
[No. 2141.] PHILADELPHIA, January 2, 1901.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the General Electric Company's Constant Current Transformer for Alternating Series Arc Lighting, reports as follows:

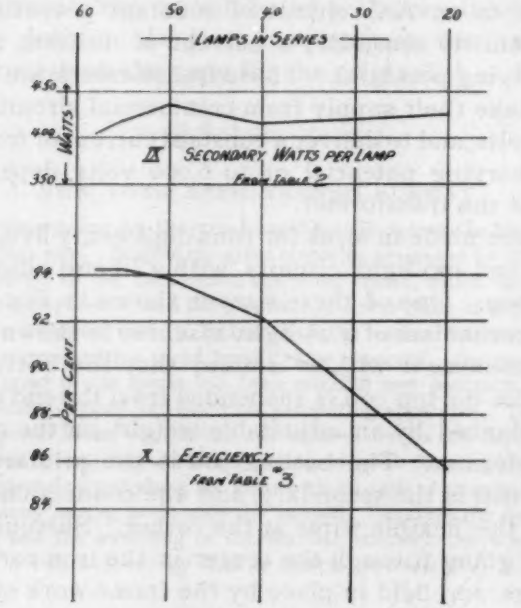
This type of transformer is intended to have its primary connected to an A.C. circuit of constant potential and to deliver from its secondary a current of uniform ampèrage but of varying potential. These transformers are regularly made to take their supply from commercial circuits of 1,100 or 2,200 volts, and to deliver a constant current of 6·6 ampères under a varying potential up to 6,000 volts, depending on the size of the transformer.

They are made in sizes for running twenty-five, fifty, seventy-five and 100 light circuits, with a liberal allowance for circuit drop. One of these sizes is shown in *Fig. 1.*

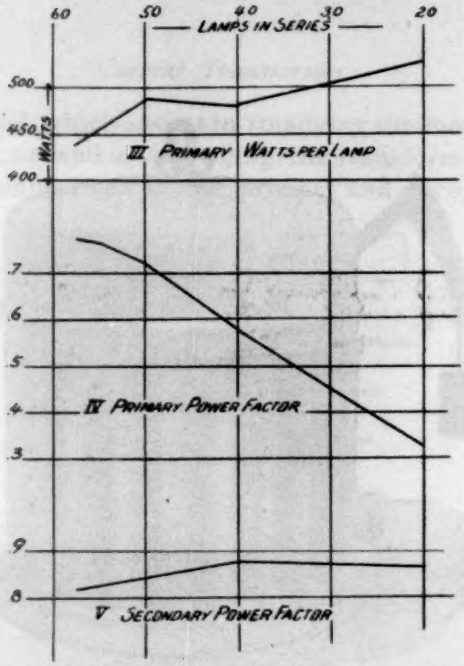
The mechanism of a 25-light machine is shown in *Fig. 2.* In this machine it will be noticed that the bottom coil is fixed, while the top coil is suspended from the end of a lever, and is balanced by an adjustable weight on the outside of the transformer. The bottom coil is the primary and the movable coil is the secondary, and the connections to it are made by the flexible wires at the corner. Surrounding the coils and going through the center is the iron core made of stampings, and held in place by the frame-work of rods and plates. When the transformer is in use, the case is filled



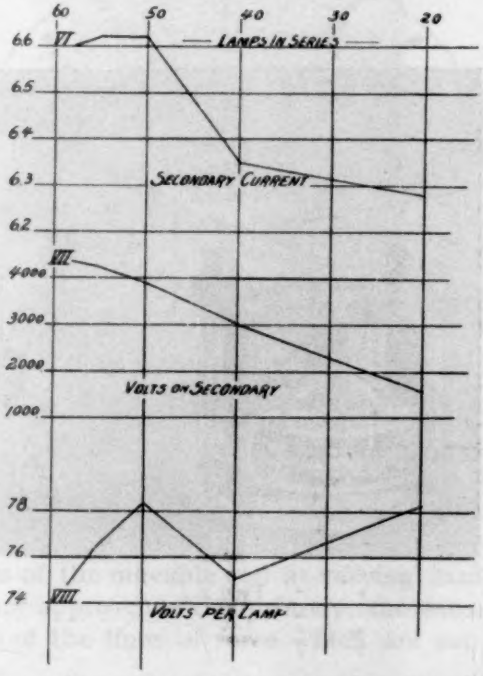
Adjustment for constant current.



Adjustment for constant Watts per lamp.



Adju tment for constant Watts per lamp from Table No. 2



Adjustment for constant Watts per lamp from Table No. 2.

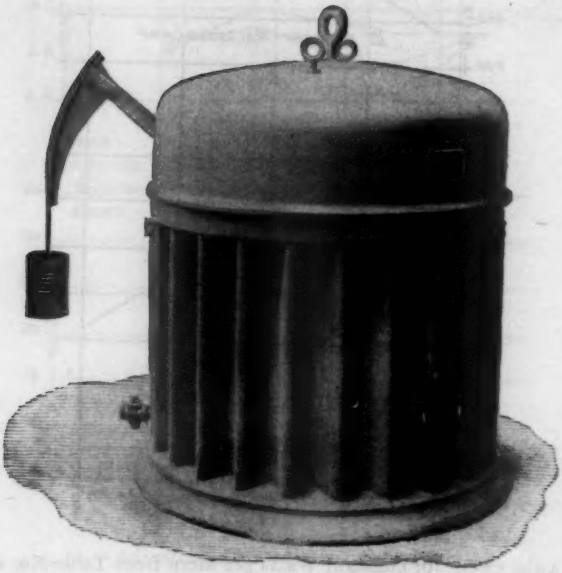


FIG 1.

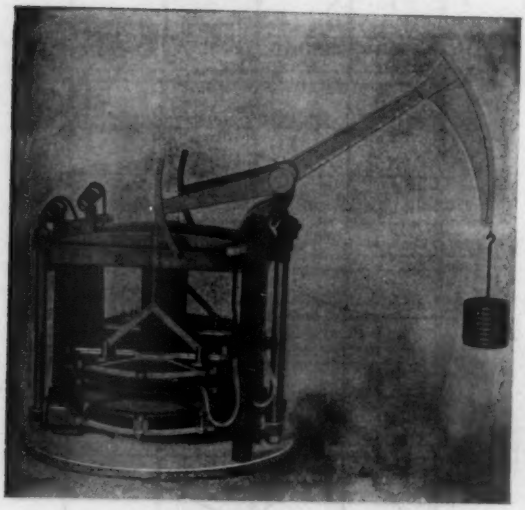


FIG. 2.

with transil oil, which assists in steadying the motion of the movable coil, as well as in cooling the transformer. *Fig. 3* shows the connections to the primary and secondary, and

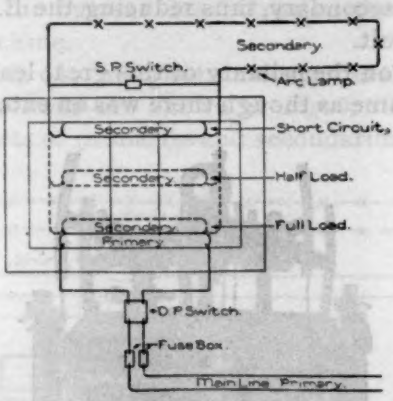


FIG. 3.

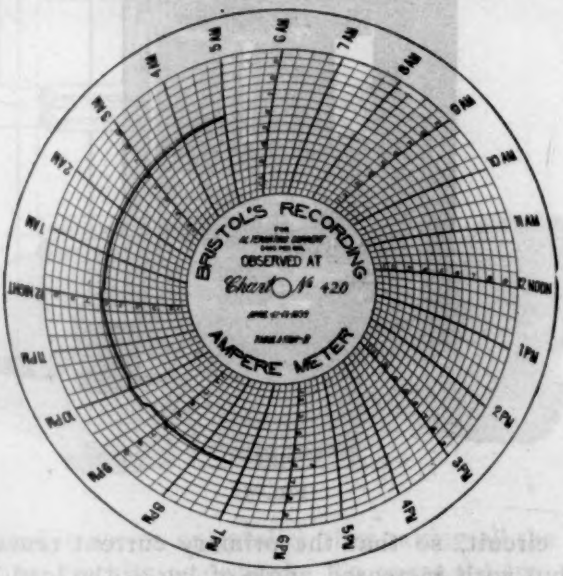


FIG. 4.

the positions of the movable coil at varying loads. When the secondary approaches the primary, the secondary embraces more of the lines of force which are set up by the

primary, and so the E.M.F. of the secondary circuit is increased. When the secondary is moved away from the primary there is more leakage of lines of force and fewer of them cut the secondary, thus reducing the E.M.F. applied to the lamp circuit.

The effect on the primary of this great leakage of lines of force is the same as though there was an external impedance

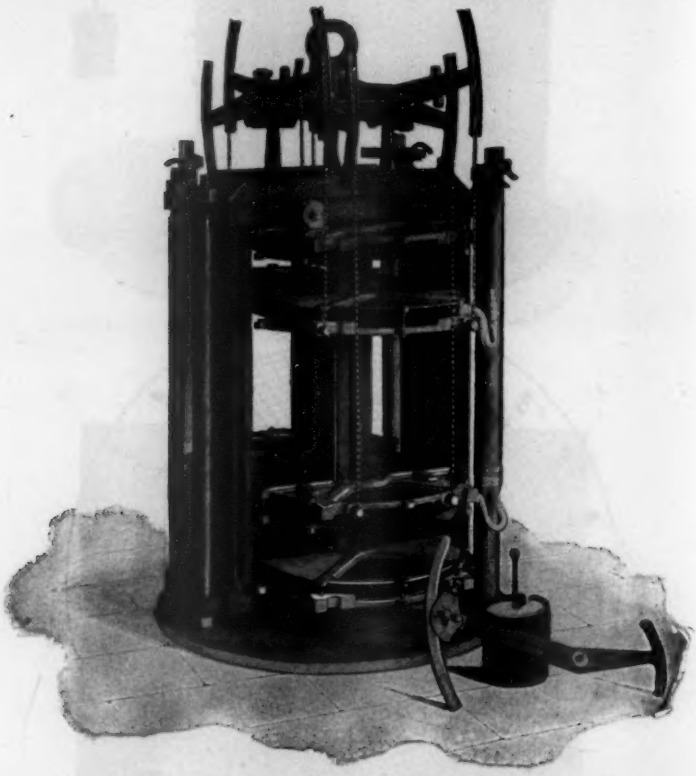


FIG. 5.

in the circuit, so that the primary current remains constant, but with increased angle of lag as the load becomes lighter.

With a change in the external circuit, the secondary, acting under the influence of the repulsion of the primary and the lifting action of the lever, assumes a new position of

equilibrium. By changing the weight on the lever the average current can be varied, while by tilting the sector on the end of the lever, and thus changing its effective length, the strength of the current can be varied throughout the range of the machine.

The mechanism of a 50-light transformer is shown in *Fig. 5*, and its connections are shown in *Fig. 6*. These larger sizes have two sets of primaries and secondaries, which may

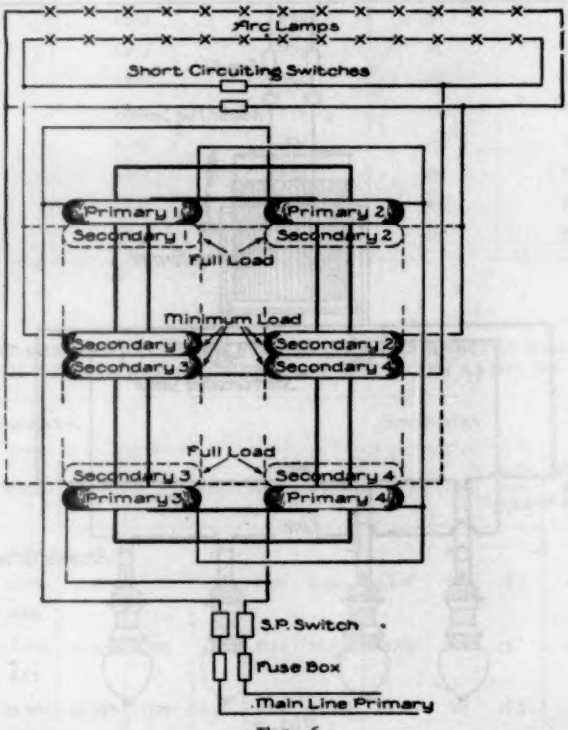


FIG. 6.

be connected in series or parallel, thus taking all the lamps in one or two circuits as desired. To cause the two secondaries to move at the same time, they are joined by the equalizing chain *A*. With this type the effect of the weight is to cause the secondaries to approach the primaries, so increasing the weight increases the current.

With the smaller size the effect of a change of weight is reversed.

Fig. 7 shows the complete connections for a transformer with its secondaries arranged to feed the same circuit.

Fig. 8 shows the secondaries feeding separate circuits.

Fig. 4 shows a record chart taken at Hartford, of an all-

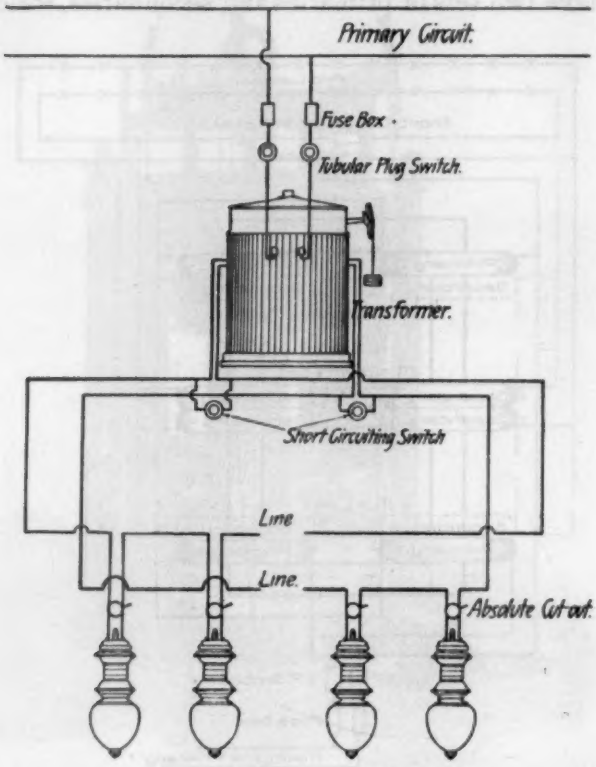


FIG. 7.

night run, which shows the variation in the strength of current.

The following data were obtained from tests on a 50-light 60-cycle, 6·6 ampère transformer, at the General Electric Company's works, in the presence of a member of the sub-committee.

TEST ON 50 LIGHT CONSTANT CURRENT TRANSFORMER, 6·6 AMPERES—60 CYCLES—CORRECTED READINGS—ADJUSTMENT FOR CONSTANT CURRENT—NO. 1.

Primary Volts.	Secondary. Volts.	Secondary. Ampérés.	Number of Lamps.	Volts per Lamp.
2,200	3,830	6·6	50	76·6
2,200	3,105	6·7	40	77·6
2,200	2,315	6·67	30	77·2
2,200	2,035	6·65	25	81·4
2,200	1,685	6·65	20	84·2
2,200	1,290	6·65	15	86
2,200	1,965	6·52	25	78·6
2,200	2,315	6·52	30	77·3
2,202	3,145	6·62	40	78·6
2,202	3,845	6·65	50	76·9

50 LIGHT CONSTANT CURRENT TRANSFORMER—CORRECTED READING WITH ADJUSTMENT FOR—CONSTANT WATTS PER LAMP—NO. 2.

Primary. Volts.	Amp.	Watts.	V × A.	Power Factor.	Secondary. Volts.	Amp.	Watts.	V × A.	P. F.	Volts per Lamp.	Watts per Lamp.	No. of Lamps.
		529										
2,200	14·78	10,580	32,500	·326	1,565	6·28	8,525	9,828	·867	78·2	426	20
		470										
2,210	14·81	18,800	32,730	·575	3,000	6·35	16,650	19,050	·874	75	416	40
		487										
2,200	14·83	23,500	32,630	·720	3,915	6·62	21,800	25,917	·841	78·3	436	50
		454										
2,200	14·83	25,000	32,630	·766	4,205	6·62	23,050	27,837	·828	76·4	419	55
		434										
2,200	14·82	25,200	32,600	·773	4,335	6·6	23,350	28,600	·816	74·7	403	58
	14·8175										420	

Figures in bold type—primary watts per lamp.

EFFICIENCY. NO. 3.

CALCULATED FROM OUTPUT AND TOTAL LOSSES.

Load.	Watts Output Measured.	Total Losses + Core Losses.	Input = Output + Losses.	Efficiency. Per Cent.
58 lamps	23,350	1,426	24,776	94·24
55 "	23,050	"	24,476	94·17
50 "	21,800	"	23,226	93·87
40 "	16,650	"	18,076	92·11
20 "	8,525	"	9,951	85·67

50 LIGHT CONSTANT CURRENT TRANSFORMER.
CORRECTED READINGS.

COPPER LOSSES—NO. 5.

PRIMARY.			SECONDARY.		
Volts.	Amperes.	Ohms.	Volts.	Amperes.	Ohms.
20	12·88		55·6	6·6	
19·9	12·86		55·7	6·6	
19·8	12 85		55·6	6.61	
19·75	12·82		55·4	6 6	
19.86	12·85	1 545	55·57	6·602	8·42

CORE LOSS—NO. 4.

PRIMARY.		
Volts.	Amperes.	Watts.
2,200	·439	720

The above was taken at 33° C.
Oil temperature reduced to 25° C. Primary resist. 1·495 ohms. Secondary resist. ·815 ohms.
C R 330 and 354.

Total losses at 33° C. = { Core loss = 720
$C^2R_P = 1{\cdot}545 \times 14{\cdot}82^2 = 339{\cdot}3$
$C^2R_S = 8{\cdot}42 \times 6{\cdot}6^2 = 366{\cdot}7$
1426

IMPEDANCE TESTS—NO. 6.

COILS APART.			COILS TOGETHER.		
PRIMARY.		SECONDARY.	PRIMARY.		SECONDARY.
Volts.	Amperes.	Amperes.	Volts.	Amperes.	Amperes.
2,040	14·76	6·6	326	14·52	6·6

These tests were made on a transformer which had been in commercial service some months. Current was supplied from an alternator driven by a D.C. motor, which by field regulation allowed the current to be kept at 60 cycles.

An inspection of curve I shows the regulating power of the transformer, when set to give constant current, the greatest variation being 1·5 per cent. from the normal.

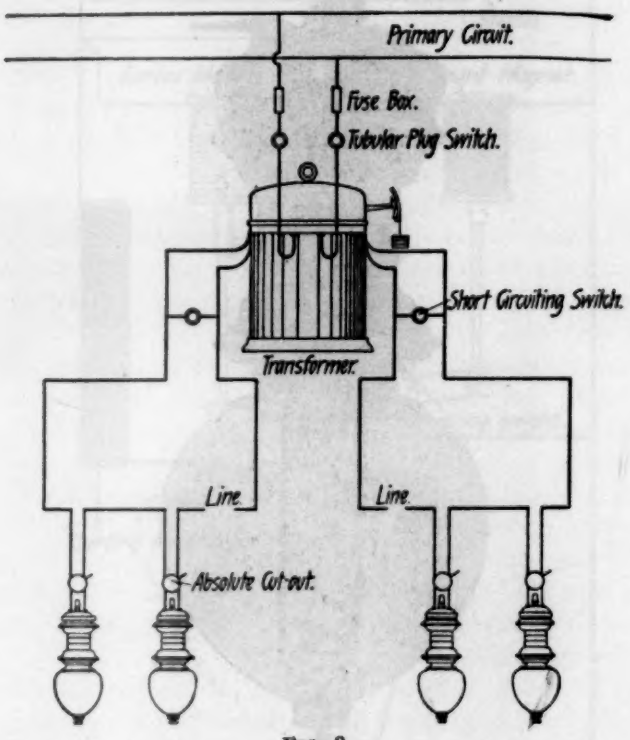


FIG. 8.

Curve II shows rather an interesting phenomenon, namely, that the voltage and watts per lamp increased as the number of lamps was reduced.

This action has caused the makers to adjust the transformers so as to give approximately constant watts per lamp, as in curve IX. This has the effect of reducing the current as shown in VI.

This rise in voltage with light loads was explained by the alteration in the current wave form, the curve becoming less peaked and more in the shape of a sinusoid.

The primary power factor, curve IV, points clearly to the fact that these transformers should be so selected as to work nearly full load.

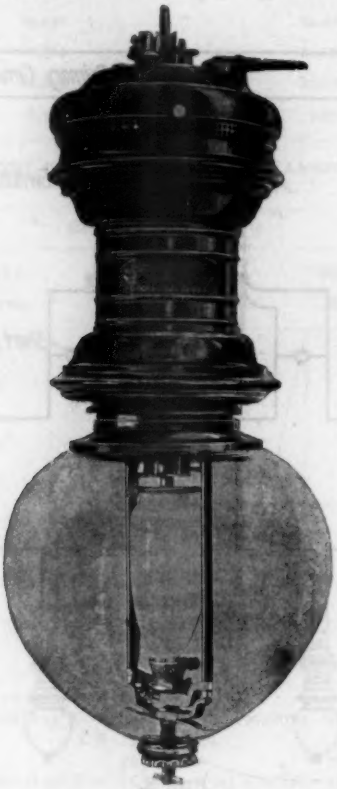


FIG. 9.

The efficiency at full load is fair, and holds up well to two-thirds full load.

A station distributing at commercial constant potential voltage, say 1,100 or 2,200, could, by using a self-adjusting reactive coil, operate circuits of thirteen or twenty-six lamps, depending on the station. To operate commercial

circuits of fifty or more lamps, additional step-up transformers would be necessary.

In considering the efficiency of a constant current transformer, we should not then simply make comparison with

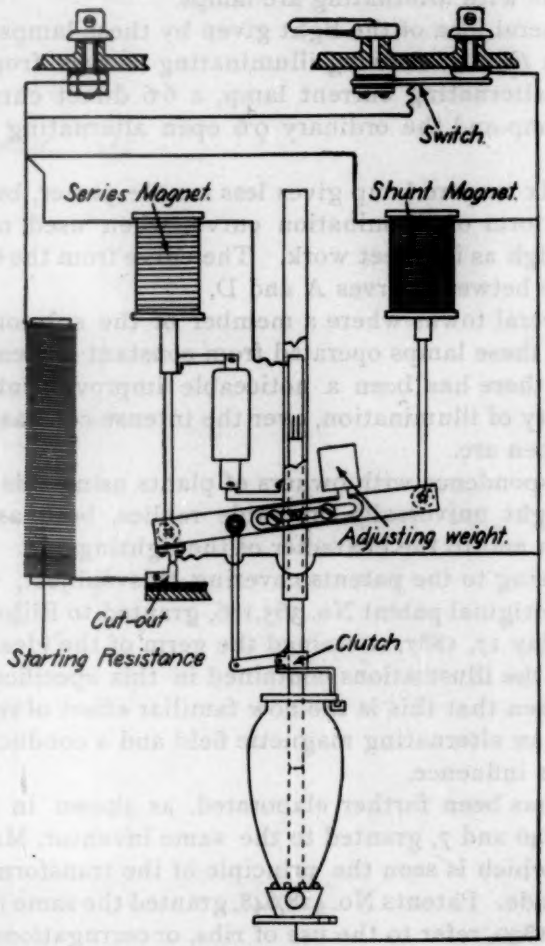


FIG. 10.

the efficiency of a constant potential transformer of similar size, for the reason that this machine is not only the step-up transformer, but the regulator as well.

The power factor of the secondary is shown in V. The

lamps used on this circuit were the G.E. enclosed arc form 3. This lamp, its mechanism and diagram of connections is shown in *Figs. 9* and *10*. It is a differential lamp and those in use were free from the usual humming sound so noticeable with alternating arc lamps.

A general idea of the light given by these lamps can be had from *Fig. 11*, showing illuminating curves from a six ampère alternating current lamp, a 6·6 direct current enclosed lamp and the ordinary 9·6 open alternating current lamp.

The six ampère lamp gives less candle power, but gives a better form of illumination curve, when used on poles 25 feet high as in street work. The curve from the 6·6 lamp would lie between curves A and D.

In several towns where a member of the sub-committee has seen these lamps operated from constant current transformers, there has been a noticeable improvement in the uniformity of illumination, over the intense contrasts made by the open arc.

Correspondence with owners of plants using this system has brought universally favorable replies, both as to the operation and to the character of the lighting.

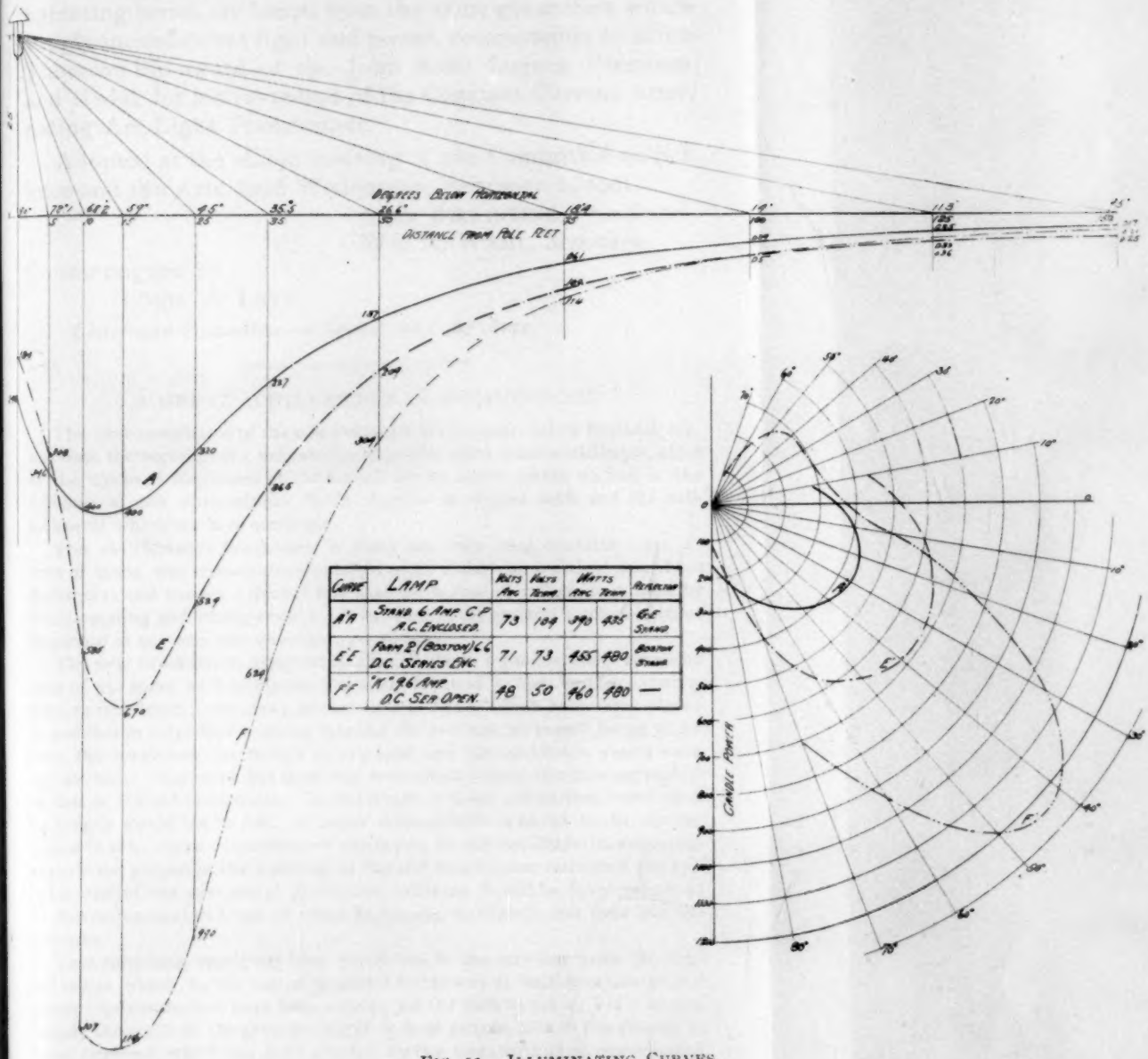
Referring to the patents covering this subject, we find that the original patent No. 363,186, granted to Elihu Thomson on May 17, 1887, contained the germ of the idea.

From the illustrations contained in this specification, it will be seen that this is the now familiar effect of repulsion between an alternating magnetic field and a conductor subject to its influence.

This has been farther elaborated, as shown in patents No. 516,846 and 7, granted to the same inventor, March 20, 1894, in which is seen the principle of the transformer as it is now made. Patents No. 428,648, granted the same inventor May 27, 1890, refer to the use of ribs, or corrugations, on the case containing the coils, and to filling the case with oil to assist in dissipating heat.

From the above it appears that this transformer is the invention of Elihu Thomson.

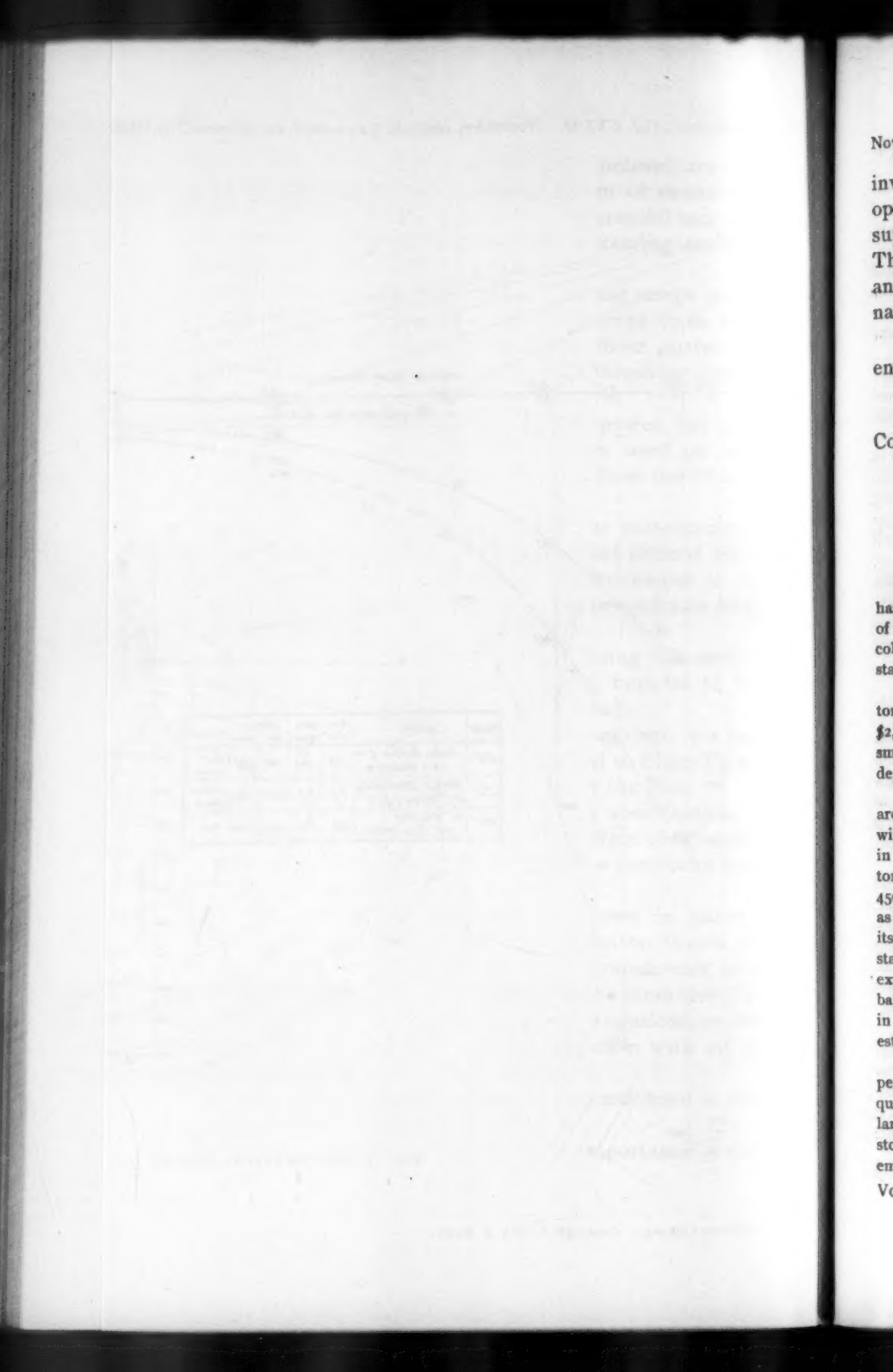
The Franklin Institute, in view of the importance of the



CURVE	LAMP	VOLTS ARC.	VOLTS TERM.	WATTS ARC.	WATTS TERM.	REFLECTOR
A'A	STAND 6 AMP. C.P. A.C. ENCLOSED.	73	104	390	435	G.E. STAND
E'E	FORM 2 (BOSTON) 6.6 D.C. SERIES ENC.	71	73	455	480	BOSTON STAND
F'F	"K" 96 AMP. D.C. SER. OPEN.	48	50	460	480	—

FIG. 11.—ILLUMINATING CURVES.

(General Electric Company. Copyright by D'A. R. Ryan.)



invention, providing as it does such an excellent method of operating series arc lamps from the same generators which supply incandescent light and power, recommends to Elihu Thomson the award of the John Scott Legacy Premium and Medal, for his invention of the Constant Current Alternating Arc Light Transformer.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, February 6, 1901.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by
LOUIS E. LEVY,
Chairman Committee on Science and the Arts.

A GREAT ACHIEVEMENT IN ENGINEERING.

The near completion of the new Delaware Breakwater, below Philadelphia, has been the occasion of a noteworthy statement from General Gillespie, chief of the Corps of Engineers of the United States Army, which we find in the columns of the Philadelphia *Public Ledger* of August 29th, and the substance of which we here condense.

The old Delaware Breakwater is about one mile long, contains 1,231,587 tons of stone, was seventy years (1828 to 1898) under construction, cost about $2,807,000, and created a limited and shallow harbor of refuge, now used by small coasting and fishing vessels. In building it the greatest amount of stone deposited in any one year was about 32,000 tons.

The new breakwater, designed in 1892, is about 1·5 miles long, covers an area of 552 acres, with minimum low-water depth of 30 feet, besides 237 acres with 24 feet depth; contains 1,464,410 tons of stone, which have been placed in position in forty-four working months, the average per month being 32,300 tons, the maximum per month 62,719 tons, and the maximum year's work 450,460 tons. The work has thus been done about twenty-five times as rapidly as that of the old breakwater. As to its cost, a direct comparison based upon its length would not be fair. A better measurement is found in the circumstance that in 1892 a commission of engineers, basing its calculations upon the experience gained in the building of the old breakwater, estimated the probable cost of the new one at $4,665,000; whereas, it will be fully completed in November next at a cost of about $2,239,334, or slightly less than half the estimate.

This surprising result has been partly due to the very low price ($1.18¼) per ton at which, by the use of powerful machinery at both breakwater and quarry, the contractors have been able to put the rock in place; but it is also largely the result of the great saving of at least 500,000 tons in the amount of stone required, which has been effected by the new method of construction employed. Without going into a detailed description of this method, we may

say that it consists essentially in adopting for the submerged portion of the breakwater a cross-section determined by the action of the sea itself, instead of a much flatter slope, such as was previously supposed (without experimental reason) to be necessary. Lieutenant-Colonel Charles W. Raymond, the engineer in charge, is entitled to the credit of having proposed this bold innovation, secured for it, by his arguments and experimental proofs, the approval of the Board of United States Engineers, and supervised its execution with vigilance and intelligence. In the words of General Gillespie the work is "a monument to his efficiency and skill as an engineer."

During the progress of its construction the new Delaware Breakwater has been visited by many engineers and has been watched with great interest, as certain, if successful, to mark a memorable advance in the methods of harbor engineering. Thus far the minutest observations have failed to detect the least sign of weakness or inadequacy in the novel submarine section employed. For the local conditions there is no doubt that the plan is successful. Whether it can be employed, and how it would have to be modified for other localities and conditions remains to be determined. The theory of it—namely, that in any locality the sea itself should be allowed to determine the submerged section for a breakwater, or, in other words, that the talus of the broken stone should be that which the sea has been found to form, and thereafter not to disturb—seems to be universally applicable. At all events, no great structures of this class will be undertaken hereafter in the civilized world without careful consideration of this new American precedent.—*Engineering and Mining Journal.*

RIVER PROFILES.

An interesting and valuable publication of the Department of Hydrography of the United States Geological Survey on the "Profiles of Rivers in the United States," by Henry Gannet, has just been published, and is now available for distribution. It embodies within 100 pages the leading facts of about 150 of the most important rivers and streams of the country, noting their length, drainage area, the location of water power in their course, their peculiarities of flow and the nature of their drainage basins.

The rivers selected are those which are the largest in size and bear most directly upon the varied interests of the country, such as the Connecticut, Hudson, Susquehanna, Ohio, Potomac, Mississippi, Missouri, Platte, Colorado, Sacramento, Columbia and others. The figures for the tables showing height above sea level and fall per mile were collected from various sources. Some were obtained from the reports of the Chief Engineer of the United States Army, some from railroad companies when their lines cross the stream, and some from the atlas sheets of the United States Geological Survey.

In the case of such rivers as the Connecticut, Susquehanna, Mississippi and Colorado, where the surrounding country is in part or whole of peculiar physiographic interest, very excellent and vivid descriptions of its leading physical characteristics are given, which add to the interest and render it valuable from an educational standpoint in geographic and physiographic instruction.

The pamphlet is the result of much careful work, and is the first attempt to collect and compile this information in its present form. W.

THE DIESEL MOTOR.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the Invention of Rudolf Diesel, of Munich, Bavaria.*]

HALL OF THE FRANKLIN INSTITUTE,
[No. 2016.] PHILADELPHIA, March 23, 1901.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Diesel Motor, reports as follows:

The Diesel Motor is an improved motor of the class known as "internal combustion" engines, and therefore, before beginning an examination of its claims to novelty and award, a brief review of the principles of such motors may be appropriate.

Practically all modern internal combustion motors, including the Diesel, operate upon a cycle first enunciated by Beau de Rochas in 1862, in which the combustible, either gas or hydro-carbon vapor, is introduced in one stroke, compressed in the next, ignited and burned in the third, and exhausted in the fourth, there being but one power stroke in every four.

The principal feature in all engines of this class has been the compression of the charge, it having been found that by using the momentum of the flywheel to compress the charge of mixed combustible and air, a notable economy and ease of working was effected. This principle was first practically utilized by Otto, in 1876, and his engine has been extensively used, both in Europe and America, principally employing illuminating gas as fuel. Various trials have shown for such engines a thermal efficiency decidedly higher than the steam engine, the proportion of heat converted into work ranging from 17 to 22 per cent. in various instances, while in the case of the steam engine and boiler combined 12 per cent. thermal efficiency is considered high,

and has been attained only by large engines under favorable conditions.

In 1897, Herr Rudolf Diesel read a paper before the Verein Deutscher Ingenieure, at their convention at Cassel, describing his studies in internal combustion motors, and his successive attempts to realize his ideas in practice. Herr Diesel began by assuming that the highest efficiency would be realized by the accomplishment of the Carnot cycle, and then proceeded to devise a motor in which, so far as was practicable, this cycle should be produced in actual operation.

The Carnot cycle is formed of two isothermal, and two adiabatic curves, the expansion during the reception of heat being such as to maintain a constant temperature. When the addition of heat ceases the temperature falls in consequence of work done, giving a curve of adiabatic expansion. During the return, heat is withdrawn in proportion to the reduction of volume, and the curve is again isothermal. The compression is adiabatic, and in the pure Carnot cycle the gas has again returned to its original volume.

Mr. Diesel has attempted to realize, within the limitations of practice, this cycle in his engine, and in so doing has produced a motor of very high thermal efficiency. In order to accomplish this result it was evident that a much higher degree of compression was necessary than that used in existing motors, since it was demanded that the charge be compressed adiabatically to the maximum initial pressure at which the motor was to be operated, this pressure not to be exceeded by the gases generated during the combustion. Such a compression would naturally produce an increase in temperature sufficient to ignite the combustible, and hence it became apparent that the fuel must not be introduced with the air but that the air must first be compressed adiabatically and that the fuel must then be introduced and burned during the out-stroke of the piston isothermally, if the desired cycle was to be practically realized.

Here a practical feature of importance appears. In all existing internal combustion motors, the question of the

ignition of the charge has been one upon which much ingenuity has been expended. In the early Otto engines, a small flame was employed, acting through openings in an ingeniously constructed slide valve; the flame being blown out by each ignition and relighted from a fixed gas burner. This was followed by the invention of the incandescent tube by Daimler, and this again by the use of the electric spark, and at the present time nearly all internal combustion engines use either the hot tube or the spark ignition.

In the Diesel motor, however, the high temperature attained by the compression of the air is sufficient to provide for the ignition of the combustible, and it is only necessary for the fuel to be injected into the heated air for its ignition and combustion to take place.

In this theoretical discussion of the subject, Mr. Diesel laid down four conditions as essential to the realization of the highest economy:

First, that the combustion temperature must be attained not by the combustion, and during the same, but before, and independent of it, by the compression of pure air.

Second, that this is best accomplished by deviating from the pure Carnot cycle to the extent of combining two of the stages of the cycle, and directly compressing the air adiabatically, instead of first isothermally from 2 to 4 atmospheres, and then adiabatically to 30 or 40 fold.

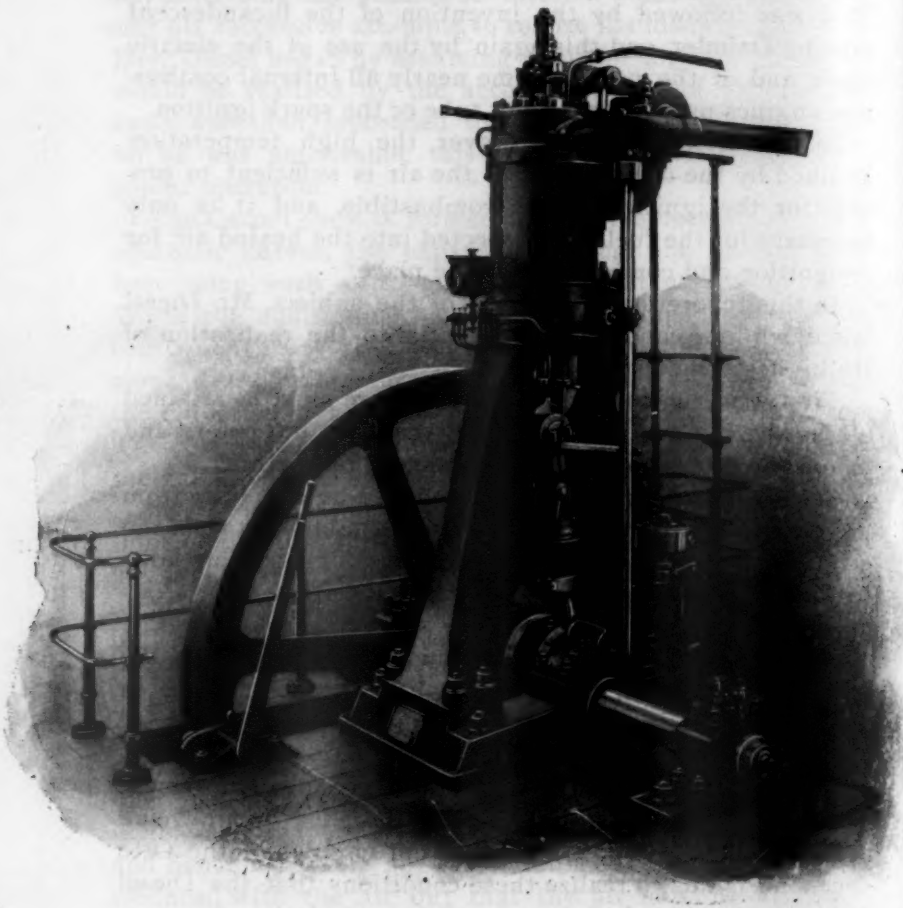
Third, that the fuel be introduced gradually into the compressed air, and burned with little or no increase in temperature during the period of combustion.

Fourth, that a considerable surplus of air be present.

It will be seen from these conditions that a motor to meet them, although operating upon the so-called "four-cycle" principle, must differ essentially from engines of the Otto tpye, and it was to realize these conditions that the Diesel Motor, as presented to the committee, was designed.

The general construction of the 20-horse power motor examined by the committee is seen by reference to the illustrations. It resembles in design a vertical steam engine of the marine type, except that all parts are built to stand the high pressures employed. The working cycle is as follows:

On one down-stroke the main cylinder is completely filled with pure air, the next up-stroke compresses this to about 35 atmospheres, creating a temperature more than sufficient to ignite the fuel. At the beginning of the next down-stroke, the fuel valve opens, and the petroleum, ato-



Twenty horse-power Diesel engine, German type.

mized by passing through a spool of fine wire netting, is injected during a predetermined part of the stroke into this red-hot air, resulting in combustion controlled as to pressure and temperature. This injection is made possible by

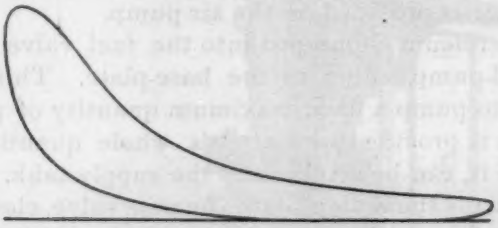
the air in the starting tank, which is kept by the small air-pump at a pressure some 5 or 10 atmospheres greater than that in the main cylinder. A small quantity of this air enters with the fuel charge, which it atomizes as described. When the motor is running at full load, a very small quantity of injected air suffices, and the pressure in the air tank steadily rises. At half load, with less fuel injected, more air passes in. For this reason, the starting tank is made large enough to equalize these differences, and a small safety valve is provided on the air-pump.

The petroleum is pumped into the fuel valve casing by a small oil-pump bolted to the base-plate. This pump is arranged to pump a fixed maximum qnantity of petroleum. A by-pass is provided so that this whole quantity, or any portion of it, can be returned to the supply tank. The governor controls the action of this by-pass valve, closing it just long enough to compel the exact quantity of the fuel required to pass into the fuel valve casing. The full charge of air being always supplied for complete combustion, it matters not whether the governor permits one or fifty drops of petroleum to enter the working cylinder at each motor stroke, the combustion is always complete. To stop the motor it is only necessary to close the valve which admits the petroleum into the fuel valve casing. The valve gear consists of a series of cams placed on a shaft journalled on brackets cast on the cylinder.

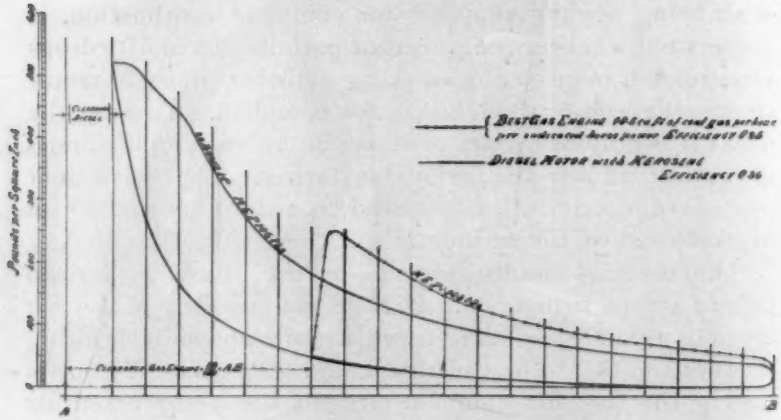
The especial claims covered by the Diesel American patent are in substance: (1) The compressing of the air alone to a point producing a temperature above the igniting point of the fuel to be consumed, and then gradually introducing the fuel for combustion into the compressed air while expanding against a resistance sufficient to prevent an essential increase of temperature and pressure, then discontinuing the supply of fuel and further expanding without transfer of heat; (2) the means in combination with the general details of the motor, for opening the valve and admitting the fuel at the beginning of the stroke, and of cutting it off at a predetermined part of the stroke, *i. e.*, of governing by controlling the duration of the combustion;

(3) of the combination, with the above operations, of a reservoir of compressed air for the purpose of starting the engine and of introducing the fuel.

The extent to which the theoretical results are realized is seen in the indicator diagrams, an example of which is appended. The chairman of your committee has witnessed the operation of the 20 horse-power engine tested in New York City by Professor Denton, and can confirm the fact



Full load, 180 revolutions.



that diagrams similar to the attached were produced from the engine during its operation.

The results of tests of the Diesel motor are very harmonious, although made by several observers at distant points from each other. Thus, the test made in Germany by Professor Schröter showed an indicated thermal efficiency of 34·2 per cent. at full load, and 38·5 per cent. at half load; and an effective thermal efficiency (based on brake horse-power) of

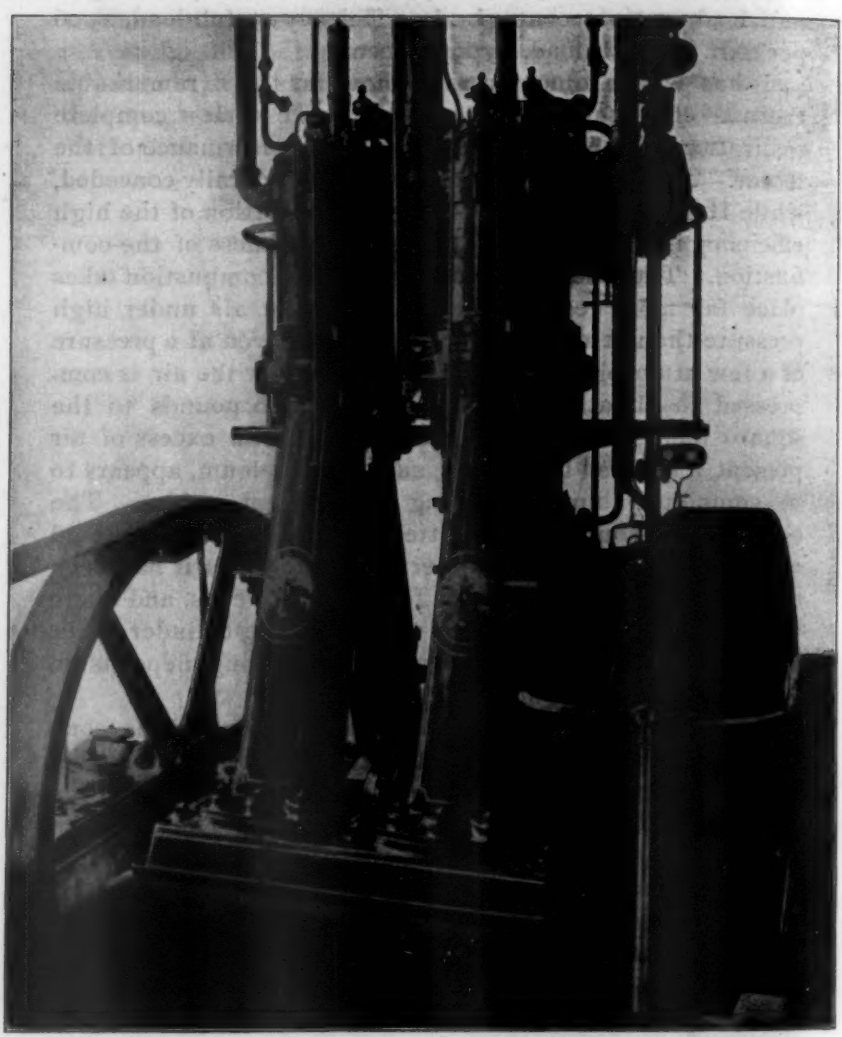
25·7 per cent. at full load and 22·4 per cent. at half load. The tests of Professor Denton in New York showed similar results, *i. e.*, indicated efficiency at full load, 37·2 per cent., at half load, 41·2 per cent.; brake efficiency at full load, 25·06 per cent.; at half load, 19·09 per cent.

It has been a question as to how far these remarkable thermal efficiencies are due to the more or less complete realization of the Carnot cycle in the performance of the motor. That they are partially so is generally conceded, while Herr Diesel himself admits that a portion of the high efficiency is probably due to the completeness of the combustion. There seems to be no doubt that combustion takes place far more readily and completely in air under high pressure than at atmospheric pressure, or even at a pressure of a few atmospheres. In the Diesel motor the air is compressed to about 35 atmospheres, say 500 pounds to the square inch, and at such pressures, with an excess of air present, a sprayed liquid fuel, such as petroleum, appears to be completely burned, leaving no trace of residue. The chairman of your sub-committee was present when the lid was removed from the cylinder of a motor after it had been running almost continuously for several weeks, and there was no trace of deposit to be seen upon the cylinder walls, while the exhaust, when the motor is running, deposits no discoloration upon a sheet of white paper.

That a portion of the high economy is due to the complete combustion in a mass of highly compressed and heated air appears to be true, and this is an essential feature of the motor.

During the summer of 1900 the chairman of your sub-committee had the opportunity of examining and photographing the 75 horse-power motor exhibited by the Augsburg Machine Works at the Paris Exposition at Vincennes, and personally took a number of indicator cards which correspond closely with those which have been published at various times. The exhaust of this engine was entirely free from smoke or visible discharge, and did not soil a handkerchief held within a foot of the end of the exhaust pipe. He also had the opportunity of visiting the works of the

Vereinigte Maschinenfabrik, Augsburg, und Maschinenbaugesellschaft Nürnberg Aktien Genellschaft, at Augsburg, where all the experimental work has been performed,



Sixty horse-power Diesel engine, German type.

and there had the opportunity, under the personal guidance of Herr Diesel, of examining the early models and machines

and the experimental laboratory, where all the investigations have been conducted.

An interesting feature relating to the motor, and one which, in the opinion of your committee, should render it especially suitable for award, is the thoroughly scientific manner in which the whole execution has been worked up from previously-conceived theoretical study. The various thermal cycles were first examined and studied, and that of Carnot was selected as conducing to the maximum thermal efficiency. The modifications in this cycle necessary to enable it to be approximately realized in practice were then studied. The various fuels available were tested, chemically and thermally, the laboratory at Augsburg containing a great number of samples, labelled with the results of chemical analysis, and the record of calorific value as found in the Junker calorimeter. The indicator diagrams obtained from the engines in actual practice agree so closely with those set out to be obtained according to the theoretical investigations, that it is, in the opinion of your committee, a noteworthy example of the true manner in which science and practice should be joined in actual work.

The chairman of your committee had the opportunity of being present, as delegate of the American Society of Mechanical Engineers, at the Mechanical Congress at Paris during the Exposition, and in the discussion of the Diesel Motor which there took place the following points were brought out:

An internal combustion motor should have the following features realized in its action to the greatest possible extent:

(1) There should be as complete a sub-division as possible of the combustible and as thorough a mixture as practicable of it with the air.

(2) The air used in the combustion should be raised to as high a temperature as possible.

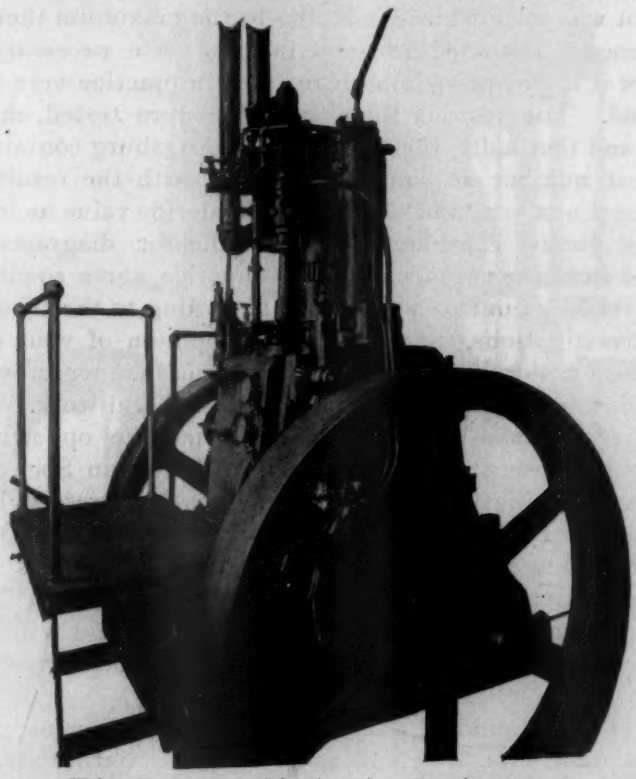
(3) All previous vaporization of the combustible should be avoided, and there should be no separation of it into light and heavy constituents.

(4) Any contact of the combustible with the more or

less cold walls of the combustion chamber should be avoided.

(5) There should be no previous mixture of the combustible with more or less cold air.

(6) The combustion should be, as far as possible, independent of the velocity of propagation of the flame and the uncertainties accompanying it.



Thirty horse-power Diesel engine, American type.

(7) The pressure should be raised as high as possible before the commencement of the combustion.

The extent to which these theoretical features have been attained in the Diesel Motor may be enumerated as follows:

(1) The sub-division of the combustible is secured by delivering it into the combustion chamber through a pul-

verizer employing air under a great excess of pressure; by means of which each particle is surrrounded with fresh air.

(2) The preheating of the air is secured by the previous compression to a degree greater than any attained by the subsequent combustion.

(3) Any previous vaporization or gasification of the combustible is entirely avoided, the fuel being introduced cold, in its normal condition, the pulverization being entirely mechanical.

(4) No contact between the combustible and the cooler walls of the combustion chamber occurs, the fuel being injected into the midst of the previously compressed air, with which it is completely consumed before it can come in contact with the walls. This is verified by the complete absence of any coating of carbon upon the cylinder walls, even after continuous runs of several months.

(5) There is, in the Diesel Motor, no previous mixture whatever of the combustible with air.

(6) There being no previous admixture of air and combustible, there can be no propagation of flame whatever, each particle burning of its own ignition due to the high temperature of the air with which it is in contact.

(7) The pressure is raised by the compression to a higher degree than is subsequently attained at any point in the stroke by the combustion.

At the Mechanical Congress at Paris, Herr Diesel reported that the latest trials with the motor have realized an indicated thermal efficiency of 40 per cent. under full load and 50 per cent, under half load. At the time when he first began his studies the best indicated thermal efficiency of internal combustion motors was 15 to 18 per cent., and in 1893, when his first publications appeared, the indicated efficiency had risen to 19 to 20 per cent.

At the first attempt the Diesel Motor gave an efficiency of 28 to 30 per cent. thus adding 50 per cent. at once to the best previous results, and this by the scientific application of previously-known principles.

All the members of your committee have not had an opportunity to consider the invention as described from a

commercial point of view, nor do they feel sure that the high thermal effects obtained are fully utilized, as there may be losses through excessive friction between the cylinder and the crank which will neutralize some of the heat gain that is claimed. Apart from this consideration, however, those members of the committee who have not been able to study the machine so thoroughly as the chairman, join in his recommendation as expressed herewith, believing that what Mr. Diesel has done is worthy of the high commendation suggested, from the Franklin Institute.

In view of the facts as above stated, which have been verified by careful personal inspection and study by the chairman of your sub-committee of motors in the United States, France and Germany, and by his exhaustive examination of the stages of the invention in the inventor's study at Munich, and the original mechanical laboratory at Augsburg, the Franklin Institute awards the Elliott Cresson Medal to Rudolf Diesel, of Munich, Bavaria, for his improvements in Internal Combustion Motors, and for his practical application in actual work of the fundamental principles of thermodynamics.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 1, 1901.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned,

LOUIS E. LEVY,
Chairman Committee on Science and the Arts.

DOUBLE-STAR ASTRONOMY.*

By Prof. Eric Doolittle University of Pennsylvania,
Member of the Institute.

To the early Chaldean astrologers who sought to read from the stars the things which the future had in store for them the appearance of the heavens was almost precisely as we see it to-day. The observer who will go out into the dark country on any starlight evening and watch the "multitude of fires" rise in the east, climb slowly upward and finally disappear in the west, will behold the spectacle which, with awful regularity, has been presented night after night since life on our world began. Even the singular grouping of stars into constellations, in which a far earlier people than the Chaldeans traced out the forms of animals and rivers and such like, has changed but little; the bands of Orion, the Pleiades, and doubtless also the Dragon, the two Bears, the River and the other constellations were as familiar to the observers of Job's day as to us.

It was inevitable that men must from the first have thought sometimes concerning this "glorious host of light," where it came from, where it went to with the rising of the sun, and why, year after year, it did not change its appearance; but it was slowly, indeed, that the true conception of our universe emerged from the fanciful speculations of the ancients. For, in the first place, much of the labor of astronomers was given up to the vain effort to find some connection between the motions of the stars and the affairs of their every-day life, and, in the second place, because the idea of a round world almost infinitely distant from the stars, though so familiar to us, must have been to them an hypothesis almost unthinkable in its absurdity. Between the years 500 B. C. and 400 A. D., however, a great advancement began, particularly in Greece and Arabia. It was during this period that there arose the great Greek philoso-

* Abstract of a lecture delivered in Association Hall on Friday, October 18, 1901.

phers, and the fathers of astronomy, Hipparchus and Ptolemy. To these it was well known that the earth was round, its size had been several times measured, and the motion of all the planets except the earth through the sky was well understood. Then succeeded the darkness of the Middle Ages when all this knowledge was practically lost, until about the year 1600, when the modern revival of scientific thought began.

The labors of Copernicus, Tycho Brahe, Galileo, Kepler and Newton now following in quick succession gave astronomy a marvellously rapid development. Thus, in less than a century, the enormous size of the sun, its true distance and the nature of the motions of the planets about it, were all discovered. But of immensely greater importance than this was the discovery of that law which regulates the motion of the earth and all the other celestial bodies, and by the aid of which the aspect of the heavens at the most remote epochs can be predicted. We shall see, also, that this same law of gravity extends to the very limits of our stellar system and that it alone is a sufficient cause of the evolution of the great double-star systems.

Before proceeding directly to our subject; let us try to get some correct idea of the comparative sizes and positions of the bodies of our universe. And in the first place it may be said that we cannot *conceive* of the magnitudes with which we shall meet. We know that the earth is eight thousand miles in diameter, but it is quite impossible for the mind to comprehend a mass of this size. We may stand looking over the expanse of a great prairie, or of the ocean, and represent to ourselves that, while the surface appears flat, it is not really so; that, at a point one mile away from us, it has curved downward about eight inches, and that if this uniform downward curving be continued for 24,000 times as far, we will have completely rounded the sphere and will approach the same plane behind us. But the magnitude so obtained is far too great for the mind to grasp. How much less, then, can we conceive of the size of the sun, whose diameter is 866,000 miles, and which would contain 1,300,000 globes as large as the earth. The best way of arriving at the rela-

tive sizes of the bodies is to make a small model of them. Thus, if we select a globe two feet in diameter to represent the sun, the earth will on the same scale be but $\frac{2}{100}$ of an inch in diameter, the size of a very small pea. We must imagine this small pea to be travelling around the globe in a circular path and at a distance of 215 feet from it. Meanwhile, if we look sharply, we will see a small shot, $\frac{5}{00}$ of an inch in diameter, moving around the pea about six inches away. This, on the same scale, accurately represents the moon. (There would be seven other particles revolving about the globe, the seven other planets, but these we need not consider.)

Imagine now this globe, with the small pea 215 feet away and the shot six inches away from the pea, set out on a level field. We know that the sun and earth are surrounded by stars in every direction; how far away on our model would the nearest fixed star be? The answer is that the nearest fixed star would be represented on the same scale by another large globe placed over 8000 miles away. This conception is of much importance, for it shows us how completely our sun with its minute attendants is isolated in space.

The sun is an immense mass of self-luminous, glowing gas at a temperature of about 18,000° F. It is contracting slowly, and must in time become solid and cold as our earth has done long ago. And as the sun is, so is the innumerable host of stars. They are merely suns, many of them vastly larger and vastly hotter than our sun, which itself is merely a faint bluish star. Whether they have minute particles, or earths, revolving about them as our sun has we do not know. It can only be said that were even the nearest star accompanied by any such planets as revolve about our sun they would be enormously much too small to be discovered by any means which we possess.

It was in the year 1609 that a telescope was turned for the first time toward the sky. One of the most remarkable of the many discoveries which at once followed was the revelation that many of the stars of the sky are not single stars, but double ones; many a star hitherto supposed sin-

gle was found to be really made up of two or more stars so close together that to the naked eye the pair, or group, must always appear as one. The first double star system ever discovered was in Ursa Major—the second star in the handle of the Great Dipper. When we consider the very crude instruments which the early observers had and the many discoveries of absorbing interest by which their researches in almost any direction were rewarded, since at that time everything was unexplored and new, it is not surprising that the significance of this one discovery was lost sight of.

One hundred and sixty-three years later, in the year 1779, Sir William Herschel turned his attention to these double stars, and for fifteen years devoted himself with tireless energy to observing them. He resolved to examine every star in the heavens with the utmost attention and under a very high power, and to measure accurately the relative positions of the stars of each pair that he might detect if there was any motion. The result of his labor was a catalogue of 10,300 double stars, the great majority of which are, however, too wide to form true double-star systems.

The life of this astronomer, who was the founder of double-star astronomy, is an inspiring one. Born to struggle and privation, it was not until his twenty-eighth year that he rose to a position as organist in a chapel at Bath, Eng., and not until his thirty-fifth year that he first looked through a small telescope. "Henceforward," says Miss A. M. Clerke, "the purpose of his life was fixed. It was to obtain a knowledge of the construction of the heavens, and to this sublime ambition he remained true to the end." The story of how he made his own telescopes, grinding the specula by hand while his sister read to him, and how, gradually, his enthusiasm and boundless perseverance led to his wide recognition, is one well known to astronomers.

After a careful examination of the measures which he had made, Herschel gradually became convinced that in many of the double-star systems the components were actually revolving about one another, and in 1802 he demonstrated this in an elaborate memoir. Thus, for the first

time, it became known that a double-star system is composed of two immense suns which, under their mutual attraction, revolve about each other. This astonishing and unexpected discovery at once aroused the greatest interest. Here were revealed numerous systems, inconceivably remote from our solar system, greatly larger than it and totally unlike it. Would the same law of gravity, which so amply accounts for the motions of the planets and their satellites, also govern the motions of these new bodies? The motions of the double stars were henceforth to be carefully observed and the results investigated with the highest power of mathematics.

The son of Sir William Herschel was to continue his father's work, retiring for that purpose to the Cape of Good Hope that he might explore the southern sky. He possessed a very superior instrument for that day, the telescope being eighteen inches in diameter and twenty feet long, and the outcome of ten years' continuous labor was the discovery and measurement of over two thousand pairs in the southern hemisphere.

Meanwhile the great German astronomer, William Struve, beginning work in 1824 at the ill-furnished observatory at Dorpat, measured, with the utmost precision, 3112 double stars, and these measures were made with such elaboration and care that they will long remain the most important contribution to double-star astronomy ever made by one man. After the death of Struve the work was continued by his son, who, during the next fifty years, discovered many new pairs and added a vast series of measures, the value of which can hardly be overestimated.

Thus, by these and many lesser observers, the work of discovery and measurement was carried forward until 1870. Prior to this date it was held by astronomers that the field for the discovery of double-star systems had been about exhausted. The Struves, with the great telescope of Poulkova, had repeatedly and critically examined all the brighter stars of the northern sky, some 140,000 in number, and it seemed reasonable to suppose that little in the way of discovery remained to be done. Thus Sir James South, who had pur-

posed to take up this work anew, while standing in his observatory said to Prof. O. M. Mitchell, "Here, sir, you behold the wreck of all my hopes. Here I have expended thousands, but it is all over, and there's an end. Struve has reaped the golden harvest among the double stars, and there is little for me now to hope or expect." "It would be difficult," adds Professor Mitchell, "to appreciate the feelings which at this time were sweeping through the mind of the astronomer. Long-cherished visions of grand discoveries in the heavens, which for years had played round his hopes of the future, had fled forever. Another had reaped the golden harvest, and, like Clairault, who wept that there was not for him, as for Newton, the problem of the universe to solve, Sir James South could almost weep to think that another's eye had been permitted to sweep over the far distant realms of space which he had long hoped might be his own peculiar province."

In the year 1869, Mr. S. W. Burnham, an amateur astronomer of Chicago, ordered a small six-inch telescope of Abram Clark & Sons, of Cambridge. This seems an unimportant fact enough, but it was to mark an epoch in the history of double-star astronomy. For this new but enthusiastic observer, who, after a long day's work at the office gave up his nights to searching the heavens, was soon to make the first of those brilliant discoveries which have given to us nearly thirteen hundred new pairs, and have forever disposed of the idea that the Struves had more than entered the borderland of exploration. Burnham's stars are, for the most part, very close and difficult. On this account their motion is very rapid, and they will doubtless furnish as much information about the growth and nature of the stellar systems, and furnish it more quickly, than will all the earlier discoveries combined.

Among the double-star systems there are two which, from the way in which they were discovered, are of special interest.

Some who are here may have seen the following picture or rather the two following pictures, placed side by side. The first, representing Herschel in his observatory at the

end of his great telescope as, while searching over the heavens, he discovered the planet Uranus. The second showing the astronomer Le Verrier at work at his study table. Underneath the pictures is written, "Two ways of discovering a planet." For Le Verrier, while writing down figures at his table, was discovering the new planet Neptune with the same absolute certainty as that with which Herschel at his telescope discovered Uranus.

In 1844, the German astronomer Bessel, from a discussion of observations made with the meredian circle, became convinced that Sirius and Procyon, the two bright "dog stars," were each attended by an invisible companion. Not only this, but the weights of the companions, and the orbits in which they moved, were computed with accuracy before they had ever been seen by any astronomer. It was not, indeed, until 1862, that the companion to Sirius was observed for the first time, with the telescope of the Dearborn Observatory, and astronomers had to wait thirty-five years longer before the little attendant to Procyon was revealed through the great 36-inch telescope of the Lick Observatory. But in each case the excessively faint companion was found to be in the position and following the path assigned to it half a century ago.

One hundred and twenty-two years have elapsed since Herschel made his first observation upon a double star. During this period there have been about 110 astronomers who have given attention to this work. As a result, there have been catalogued about 13,000 double stars and on many of them a large number of measures have been made, though it is to be remarked that the observers are still all too few in proportion to the work to be done. Let us see what the mathematical astronomers have deduced from all this material.

In the first place, it is found that the smaller star is revolving about the larger one in an ellipse, just as the planets pursue elliptic paths about the sun, but with this important difference: that while the orbits of the planets are almost circular, the orbits of the stars are, on the whole, very much flattened—the ellipse is much longer than it is wide. Again,

by a simple application of the principle of the lever, the relative masses of the two stars of a double-star system can be readily obtained. Unlike the solar system, in which the sun is nearly 800 times larger than all the planets combined, the two components of a double-star system are of comparable, and frequently of nearly equal, mass. Evidently these systems are very unlike the solar system. They are, in short, made up of two great suns revolving about one another in exact accordance with the law of gravity; although it has not yet been rigorously proved that this is the only possible law which will account for the motions observed, yet the probability that it is the law of attraction in these systems is so great that it amounts almost to a certainty.

The recognition that the law which governs the motions of these bodies about one another is that same law which so amply accounts for the complex motions of the bodies in our own solar system has led to an investigation so vast and far-reaching that it constitutes one of the most exalted conceptions of modern astronomy.

There are in the sky a multitude of faintly shining, self luminous, cloud-like bodies called *nebulæ*. What they consist of we do not certainly know—whether they are wholly gaseous, or whether they are made up of a vast number of meteoric particles which, by their mutual collisions, give rise to the faint light which the nebulæ are seen to emit. The larger of these nebulæ are very irregular, but the smaller are usually circular or elliptical in outline, and some of them have a star at their center. Now the force of gravity acting upon such a great nebulous cloud in space will cause the particles to move ever nearer and nearer together—that is, the nebula will slowly contract, or shrink, under the influence of its own gravitation. And as it shrinks together it will grow hotter and hotter, as can be proved mathematically, until in time it will become as compact and as hot as our own sun. Helmholtz, indeed, in 1856 proved that our sun is thus steadily shrinking to the extent of about 250 feet a year, and that this contraction is the source of all the heat which we receive from it. As long as the shrinking mass remains

gaseous, it will emit light and heat, and it is believed that just before the contraction is stopped by the increasing resistance of the now nearly solid mass the heat emitted and the brightness will be greater than at any previous time.

But there is another factor to be considered. Unless we suppose an almost impossibly delicate adjustment of its particles, the nebula, as it contracts, will begin to rotate about some axis. And it will rotate faster the smaller it grows. If this rotation is not too great, the nebula will condense into a single body like our sun, but otherwise it may take a very singular form closely resembling an hour glass, or pear. This pear-shaped body, which the French mathematician Poincaré first showed mathematically to be possible, has been named the *Apioid of Poincaré.*

The contracting nebula cannot, however, long retain this pear-shaped form, which is known to be an unstable figure of equilibrium. Its future history will be as follows: The constriction separating the small end of the pear from the large end will increase until, finally, the small end is cut away and begins to revolve about the larger portion close to its surface. But two such gaseous, elastic bodies revolving so close together will raise enormous bodily tides in one another and the effect of these tides will be to push the two bodies rapidly apart. Thus, from the contracting nebula, there will have been evolved by the action of gravity alone a true double-star system. But we can trace the evolution still further than this. As long as the bodies remain plastic, the enormous tide-raising force which they exert upon one another will not only push them apart, but it will continually increase the flattening or elongation of the orbits, and we have seen that these flattened orbits are characteristic of the double-star systems.

It should be added that the *apioid* is by no means the only form which a contracting nebula may take. If the rotation is too great for this body to occur it seems probable that there will be a general thinning out of the material near the axis of rotation and that the mass will take the form of a ring; but it is to be observed that the ring is an unstable figure of equilibrium also, a temporary stage in the evolu-

tion, the next step of which we cannot foresee. And so, with a different adjustment of the rotation to the mass, still other forms can doubtless rise; but their mathematical discovery is of the utmost difficulty and it remains still unaccomplished.

Thus we have traced, briefly, what seems to have been the past history of the stellar systems. Their evolution, begun countless ages ago, will go regularly on until, at an epoch inconceivably remote, it will cease through the cooling and solidifying of the component stars. The life of man on the earth is so short compared with these immense intervals of time that the slow process of the development will be forever withheld from his direct vision. But by patient study of those laws of nature with whose action he is already acquainted, the history and aspect of the heavens in the remote ages may be revealed to him. Thus, although he may view the stars as it were but for an instant, he may come to know of them—their beginning, their life history, and their end.

ELECTROLYTIC CHROMIUM.

With a divided cell containing a chromic salt at the cathode and an acid or saline solution at the anode, good deposits of chromium can be obtained on a carbon cathode, or on platinum, brass, lead, etc., according to the experiments of Neumann, which were published in *Zeitschrift für Elektrochemie*, and abstracted in a London journal. With chromic chloride solutions containing 10 per cent. Cr, a current density per square decimeter of 0·9 ampère gave only oxide, 1·8 to 7·2 ampères gave oxide and metal, 9 to 18 gave pure metal, in the latter case mostly crystalline, with a current efficiency in densities 9 and upward of about 38 per cent. Increase of temperature hardly affects the current efficiency, but above 50° C. the metal deposits as a black powder. A strength of 16 per cent. Cr in the solution gives a yield of 57 per cent., increased to 89·5 by altering the anode solution. With chromic sulphate the best conditions are 6·7 to 8·5 per cent. Cr and 13 to 23 ampères per square decimeters, giving 84·6 to 86 per cent. efficiency. Acetate does not work well. The deposits are bright gray and lustrous, but have a tendency to peel off, due to films of oxide. They are hard and brittle and very pure, containing only 0·1 to 0·2 per cent. of iron, and, like ordinary chromium, occur both in active and passive states. The decomposition potential in chromic sulphate of five times normal strength is 1,898 volts, in the chloride 8 times normal 1,685 volts, but it is necessary to use at least double this electro-motive force.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, October 16, 1901.*]

HALL OF THE INSTITUTE,
PHILADELPHIA, Wednesday, October 16, 1901.

Vice-President WASHINGTON JONES in the chair.

Present, 148 members and visitors.

Additions to membership since last report, 15.

President Birkinbine, who assumed the chair, introduced Mr. Alex. J. Wurts, of Pittsburgh, who gave an interesting description of the Nernst incandescent electric lamp, as modified and improved by himself and associates in connection with the Westinghouse Electric and Manufacturing Co. This American type of lamp is now so far perfected that the company above named is about to place them upon the market.

Mr. Wurts recounted the numerous difficulties which had been encountered and successfully overcome in adapting the crude invention of Nernst to meet the conditions of practical service.

Mr. Wurts had installed a number of the new lamps in the lecture room, which was brilliantly illuminated.

The subject was discussed at considerable length by Messrs. C. J. Reed, Prof. Arthur J. Rowland, Carl Hering, Richard L. Binder, Spencer Fullerton and others.

(An abstract of Mr. Wurts' remarks, with the discussion, will appear in the *Journal* in due course.)

On Mr. Fullerton's motion the subject was referred to the Committee on Science and the Arts.

Prof. Rowland, numerously seconded, moved a vote of thanks to the speaker of the evening for his admirable presentation of this interesting subject. The motion passed unanimously.

Adjourned.

WM. H. WAHL,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, October 2, 1901.*]

MR. LOUIS E. LEVY in the chair.

The following reports were adopted:

(No. 2113.) *The Liszt Organs.*—The Mason & Hamlin Co., Boston, Mass.

ABSTRACT.—This subject was referred to the committee by the Bureau of Awards of the late National Export Exposition. The Liszt organ is a musical instrument whose tones are produced exclusively by reeds actuated by exhaust wind. Its development has covered a period of many years, during which

the manufacturers have improved it in every detail of tone-quality and volume, elastic and highly-responsive touch, evenness of scale, with numerous orchestral effects of real artistic merit. The development of the instrument has proceeded during the past 25 years.

The report concludes: "In recognition of the intrinsic merits of the Liszt organ, and of the skill and ingenuity displayed in its production, the Franklin Institute awards to its makers, the Mason & Hamlin Company, the Elliott Cresson Medal. [*Sub-Committee.*—H. R. Heyl, Chairman; Chas. M. Schmitz, Paul Sentz, Rich. Zeckwer, Wm. Stoll, Jr., Henry C. Wilt.]"

(No. 2150.) *The Morse Drive Chain.*

ABSTRACT.—The chain under consideration was first placed on the market as a bicycle chain, but was not satisfactory in service on account of the sprockets not being properly cut to fit it. When this defect was remedied the results were more satisfactory.

The exhibits submitted to the committee showed both patterns, but the roller feature was not considered, the rocker-pin being the vital element of the improvement.

The sub-committee visited the establishment of Wm. Sellers & Co., in Philadelphia, and examined one of these power chains operating a key-seating machine. This chain had run for several months and was working smoothly and about as quietly as a belt. The report concludes: "From all the information the committee's representatives could obtain, and on examination of the patent records, they believe that this improvement in chain construction is an important one, and is a step towards raising the efficiency of what heretofore has been an unsatisfactory method of transmitting power. The John Scott Legacy Premium and Medal is recommended to the inventor, Everett F. Morse. [*Sub-Committee.*—Geo. S. Cullen, Chairman; L. L. Cheney, J. Logan Fitts.]"

(No. 2151.) *Tobacco Cutting Machines.*—John B. Adt, Baltimore, Md.

ABSTRACT.—These machines are protected by letters-patent of the United States granted to applicant. The machines have come largely into use and perform their intended service most satisfactorily.

The principal mechanical advantage of these machines lies in the peculiar motion of the cutter knife. The down-stroke or cut is made vertically, giving an even cut, the motion of the feeding attachment being arrested while the cut is being made. The length of the cut is very easily adjusted by means of a worm, and fixed by a lock-nut, while the stroke of the ratchet on the same side of the machine is changed.

As the knife is being raised it is, by an ingenious arrangement of eccentrics, given a motion which takes it away from the tobacco which is being fed forward for the next cut. By this ingenious expedient the friction is avoided which would frequently generate sufficient heat to change the color of the tobacco, and affect unfavorably its commercial value. The distance between the two planes of action of the cutter-knife is always greater than the thickness of the next cut, the material for which is being fed forward while the knife is being raised.

The Adt machines are said to be unique in possessing this anti-friction movement of the cutters, and the great advantage which this movement affords in always leaving the tobacco with its original bright color is freely acknowledged by manufacturers who use the machines.

The material and workmanship on the machines is pronounced excellent. One machine inspected by one of the committee's members had been in operation continuously for several years, without any expense for repairs. It was running at the rate of 360 cuts per minute and was working perfectly, making a very fine cut. The usual speed is 260–275. The Adt machines finally are said to require less power to operate them than other machines of less capacity. The John Scott Legacy Premium and Medal is recommended to the inventor. [*Sub-Committee.*—Wm. F. Willcox, Chairman.]

(No. 2167.) *Color-Sense Tester.*—E. W. Scripture, New Haven, Conn.

ABSTRACT.—The purpose of this device is to test the color vision of persons engaged in occupations in which ability to distinguish colors is essential.

Light passes through white glass, then through glasses of different colors. The person under examination names the colors; from a comparison of the correct names with the names he gives, the accuracy of his color vision is determined.

The Scripture apparatus consists of a circular disk of white glass, about 8 centimeters in diameter, held in a brass frame to which a handle is attached. Over this disk is a thin sheet of metal pierced near its periphery by 10 holes regularly spaced. Attached to the center of this is an axis which carries one or more of the detachable disks. All of these are approximately the same diameter as the brass frame about the white glass.

One disk has 10 holes covered by glass of colors used in signaling. These colors are matched spectroscopically with the colors in practical use.

The second disk has 10 holes covered by glass ranging in shade from clear to smoked. The third disk has 5 holes which are uncovered. These are not equally distant, but are so located that one of them is opposite a hole in one of the previously described disks; the 4 other holes are also opposite to the holes in the other disk. All the holes so far mentioned are about 1 centimeter in diameter and are equi-distant from the centers of the disks.

The fourth disk is like the third, except that its holes are about 1 centimeter in diameter.

Method of Making the Tests.—A dark room is to be used in making tests with this instrument. The two eyes are examined separately. The color tester is fastened upon the front of a lantern, holding either an incandescent lamp or an oil flame. Three tests are made. In the first, the disc with red and green glass is placed upon the axis, and on this the disc, with five large holes. Light passes through the white glass, then through the colored glass, and travels through the five holes to the eye of the observer. He calls off the colors which he sees through the holes, following any prescribed order. Both color disc and diaphragm are turned irregularly and the calling off of the colors is continued. If any mistakes are made, a defect in color vision is proved.

In the second test, the disc with five large holes is replaced by the one with five small holes, and, as before, the observer names the colors. In this case rapidity is insisted upon, for the purpose of this test is to determine whether the central spot of the eye has defective color vision, and, if the test s conducted with deliberation, the eye may turn and permit the light to fall upon peripheral parts of the retina.

In the third test, the disc with colored glasses is put next to the white

glass; upon it the disc with various shades of smoked glass, and finally the disc with the large holes. The purpose of the disc with smoked glass is to imitate the effects of foggy and smoky air upon signal colors. By bringing each of the ten shades of smoked glass in turn before one color of glass, the transmitted light becomes in turn of ten different shades of the same color. The names of the color seen are given as in the two previous tests.

A blank form of record is to be used, on which are entered descriptive details of the person examined and the judgment of the examiner as to whether the color sense of each eye is "safe" or "not safe."

The three important parts of the tester are: (*a*) Discs of colored glass arranged around the circumference of a circle. (*b*) A series of smoked glasses to modify the colors of the discs. (*c*) The use of a small aperture to test for blindness to color in the central parts of the visional field.

Your committee finds that the circular arrangement of colored glasses was used by the L. C. & D. R. R. in England, at least as early as 1890, that the use of the modifying glasses is described in Edridge Green's book entitled, "Color Blindness," published in 1891, and that the method of testing by small apertures was shown at a conversazione of the Royal Society several years ago. Professor Scripture bases his claim "on the combination of the parts in such a way as to reproduce the mental conditions under which the engineer or pilot judges the lights." The committee finds the claim to be substantiated.

Dr. Morris, of the Reading Railroad, after examining the tester carefully, said that he regarded it as a great improvement on the wool-test, and emphasized the point that the pieces of wool soon became too much soiled to be of use while this instrument is unchanged.

The following points of advantage are noted: (*a*) Simplicity of construction. (*b*) Convenience in manipulation. (*c*) Combination of parts as to imitate practical conditions.

The report awards the Edward Longstreth Medal of Merit to the inventor for the excellent manner in which the parts of this apparatus are combined. [*Sub-Committee.*—Geo. F. Stradling, Chairman; Robt. H. Bradbury, Edward A. Partridge, F. E. Ives, Arthur W. Goodspeed.]

(No. 2179) *Combustion Crucible.*—Porter W. Spooner, Easton, Pa.

Reserved for publication in full.

The award of the Scott Legacy Medal and Premium to the inventor is recommended for ingenuity displayed in construction and the practical value of the apparatus. [*Sub-Committee.*—Harry F. Keller, Chairman; G. H. Clamer, Joseph Richards.]

(No. 2180) *Electro-Chord Piano.*—George Breed, Philadelphia.

ABSTRACT.—This invention is the subject of U. S. letters patent No. 560,679, May 26, 1896 (and others pending). The device in general consists of an ordinary piano, opposed to the springs of which is a series of electro-magnets, one for each tone and semi-tone, in a range of about five octaves, adjusted with their poles in close proximity to the strings, each magnet coil forming a portion of an electrical circuit in which are also a contact breaker beneath the corresponding piano key and a current-interrupting device termed the pulsator, together with the necessary electric generator, and a sliding contact rheostat. Each circuit has its own magnet and contact-breaker, although in general the pulsator, generator and rheostat are common to all circuits.

[The operation of the device cannot be made intelligible without the aid of a number of illustrations.]

Among the novel features of present design of the piano are an elaborate system of electrical commutators and stops controlling their action, by the use of which certain strings may be made to respond more powerfully than certain others, or only the upper or lower tone of a chord may be made continuous, while the others die away as in the ordinary piano; or various combinations of the different qualties of tone produced by several pulsations, either on the piano frame or isolated from it, may be obtained.

The original idea of an electro-musical instrument in which the sonorous body is vibrated by a fluctuating current is not a new one, nor is the tone quality of the present instrument all that might be desired musically. The inventor has, nevertheless, attacked the problem with the display of much ingenuity in the application of his novel improvements, and particularly in the design of the variable pulsator, for which reason the award of the Edward Lonstreth medal is made. [*Sub-Committee.*—Chas. C. Heyl, Chairman; Max Levy].

(No. 2187) *Ink-Eraser.*— Deisher.

(An advisory report).

(No. 2188) *Electrolytic Method for Obtaining Metals and Nitric Acid from Fused Nitrates.*—J. V. Darling, Philadelphia.

(Reserved for publication in full.)

The following report passed first reading:

(No. 2196) *Experiment in Long-Distance Phonographic and Telephonic Transmission.* Wm. J. Hammer, New York. W.

SECTIONS.

(*Abstracts of Proceedings.*)

PHYSICAL SECTION.—*Stated Meeting*, September 25th, 8 P.M. Dr. Geo. F. Stradling in the chair. "Crystallization Under Electrostatic Stress." Dr. Paul R. Heyl. Second communication. (Abstract.) The thought underlying these experiments was that if crystals were allowed to form from solutions subjected to severe and intermittent electrostatic stress, they might bear some birth-marks of the stormy circumstances attending their formation. An alteration of interfacial angles was deemed the most likely change, and a change of density was also examined for. No effect of either kind was found in crystals of sulphur in CS_2, or in crystals of copper sulphate in water. Also solution of HgI_2 in hot alcohol and in hot HCl were used as qualitative indicators. Under electrostatic stress, this salt crystallized out in the ordinary and very unstable yellow form. It was hoped that the nascent crystals would form the more stable red modification from the beginning. The conclusion drawn is that any molecular forces called into play by electrostatic stress are not comparable with the forces of crystalline attraction.

"Recent Progress in Electricity." Dr. M. G. Lloyd. In reviewing the current literature on "Electricity," the speaker called attention to di-electric polarization by mechanical means, to the dependence of the Hall-constant upon thickness when very thin films are used, to recent measurements of thermo-

magnetic, thermoelectric and galvanomagnetic phenomena, to the theory of electrons, to recent experiments affording evidence of the non-existence of any counter E M.F. in the electric arc, and to numerous minor articles. He dilated at greatest length upon the recent discussions as to whether a moving static charge produces the same magnetic effects as an electric current, inaugurated by Crémieu's announcement that his experiments failed to show such an effect. At present the weight of evidence is in support of Rowland's famous experiment made in 1876 at Berlin, which showed the existence of the effect in question.

"Review of Recent Work in Light."—Dr. Horace C. Richards. The speaker briefly reviewed the following papers:

In the subject of refraction, F. Pockels (*Physik. Zeit.* **2,** 693) has investigated the variation in the refractive index of glass with change of density produced by pressure. The purpose of the paper is to amplify the results obtained by Pulfrich in 1892 (*Wied. Ann.* **45,** 609) on the temperature change of the refractive index, and to test the various formulæ connecting refractive index with density.

In spectroscopy, work has gone on in the accumulation of data, the chief interest being the grouping of lines in series and the search for numerical relations. Mention may be made of the work of H. Lehmann (*Ann. Phys.* **5,** 633) on the ultra-red spectra of the alkali metals; that of Lockyer and Baxandall (*P.R.S.* **68,** 189) on the arc spectrum of vanadium; and that of Schenck (*J.H.U. Circ.* **20,** 79) on the cadmium spectrum.

An interesting theoretical paper by W. Sutherland (*Phil. Mag.* [VI] **2,** 245) on the cause of the structure of spectra seeks to explain Balmer's and Rydberg's laws by the hypothesis of electrons revolving about vibrating atoms.

K. Angstrom has contributed a paper (*Ann. Phys.* **6,** 163) on the absorption of radiation by carbon dioxide, showing that while increase of the thickness of the column of gas merely darkens the absorption bands, increase of density broadens them.

R. W. Wood has published several papers on the anomalous dispersion of cyanin and carbon (*Phil. Mag.* [VI] **1,** 36, 405, 624) measured by interference and by refraction through thin prisms. Another paper by him (*Phil. Mag.* [VI] **1,** 551) on the abnormal refraction of sodium vapor is of significance in the theory of the solar "flash-spectrum."

In the domain of psycho-physical optics, a paper by S. Bidwell (*P.R.S.* **68,** 262) describes his later investigations on the "negative after-image" produced in the eye by a brief flash of color after a period of rest.

The most striking of the recent advances have been in the theoretical development of the laws of the distribution of radiation in the spectrum of an "ideally black" body. The most recent result is that derived by M. Planck (*Verh. Dts. Phys. Ges.* **2,** 202) by assimilating the radiating molecules of matter to Hertz resonators; and this theory has been subjected to rigid experimental scrutiny by Paschen (*Ann. Phys.* **4,** 277) by Rubens and Kurlbaum (*Ann. Phys.* **4,** 649) and by Lummer and Pringsheim (*Ann. Phys.* **6,** 192). The result seems to be that while Planck's formula is a very close approximation to the truth, there are small systematic deviations. The most remarkable contribution in this subject is by Planck (*Ann. Phys.* **4,** 553, 564)

where he shows how the law of radiation and the kinetic theory of gases lead to the determination of molecular constants, such as the number of molecules in a cubic centimeter of gas, etc.

E. Pringsheim has contributed (*Vehr. Dts. Phys. Ges.* **3,** 81) a theoretical derivation of Kirchoff's law connecting emission and absorption, which seems free from objection.

The radiation of bodies not ideally black has also been investigated. Lummer and Pringsheim (*Verh. Dts. Phys. Ges.* **3,** 36) have used the law of radiation to obtain limiting values for the temperature of several incandescent bodies, and E. L. Nichols (*Phys. Rev.* **13,** 65, 129) describes an investigation of the comparison of the visible radiation of carbon with that of the acetylene flame.

Dr. Richard's communication was discussed by Mr. Hugo Bilgram and Professor Hoadley, and Dr. Lloyd's by Drs. Stradling, Seal and Meeker.

On motion of Dr. Meeker, a vote of thanks was tendered the gentlemen who presented papers. JESSE PAWLING, JR., *Secretary.*

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—Proceedings of the *Stated Meeting*, held Thursday, October 3, 1901, at 8 P.M. Dr. Chas. F. Himes in the chair. Present, 16 members and visitors.

The Executive Committee, through Dr. Leffmann, reported informally on the season's program of communications.

The Special Committee appointed at the previous meeting to prepare and present a scheme of Photographic-Record Work for the section, presented a report, which was read.

The Executive Committee, through Dr. Leffmann, gave an informal report of the present state of the subject of the proposed photographic exhibition, from which it appeared that no definite plan had yet been decided on.

The report of the Special Committee on Record Work was taken up for consideration. Mr. Ridpath and Mr. Wanner exhibited several styles and sizes of albums and commented on them. Criticisms were offered by the chairman on the absence in the classification of any reference to scientific records, and on the specification of size of pictures. The subject was very fully discussed by Messrs. Leffmann, Ridpath, Truscott and others. The drift of the discussion disclosed the general sentiment to be in favor of an extension of the plan of classification to include the scientific element, but not to curtail the general scope of the same.

On Dr. Leffmann's motion, duly seconded, it was finally

Resolved, To refer the report back to the Special Committee with instructions to extend the proposed classification so as to include specifically subjects of scientific interest; also, that the Special Committee be given power to act, and that the members be invited to transmit suggestions to the committee.

WM. H. WAHL, *Secretary pro tem.*

MINING AND METALLURGICAL SECTION. Thirty-third *Stated Meeting*, held Wednesday, October 9th. Vice-President James Christie in the chair. Present 15 members and visitors.

The evening's communications were devoted to a series of informal talks on the metallurgical arts at the Pan-American Exhibition, participated in by Messrs. Birkinbine and Christie.

Mr. Wm. R. Webster, by invitation of the chairman, made some interesting remarks on recent progress in the manufacture of rails. He also made reference to the paper of Mr. Risdale, read at the recent meeting of the British Iron and Steel Institute, Glasgow, and commented on a table made up by that author, exhibiting the different types of faults in steel, and the causes of their development.

Mr. A. E. Outerbridge made some remarks on iron cast in iron moulds, and its use in foundry work.

Mr. J. S. Jeans, one time Secretary of the British Iron and Steel Institute, a visitor, was introduced by the chairman, and made some happy informal remarks on the industrial conditions prevailing in Great Britain and the United States, more especially bearing on the iron and steel industries.

Mr. Christie closed the meeting with some comments on the remarks of the last two speakers, and added some comments of his own on the possibilities of the future utilization of low-grade iron ores after concentration, especially in the open-hearth process. WM. H. WAHL, *Secretary pro tem.*

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting* held Thursday, October 10th, 8 P.M. Mr. James Christie in the chair. Present 104 members and visitors.

The subject for discussion was "The Construction and Inspection of Steam Boilers," with especial reference to the "City of Trenton" disaster.

The subject was announced by the chairman in a few appropriate remarks, and Mr. Samuel M. Vauclain was invited to open the discussion.

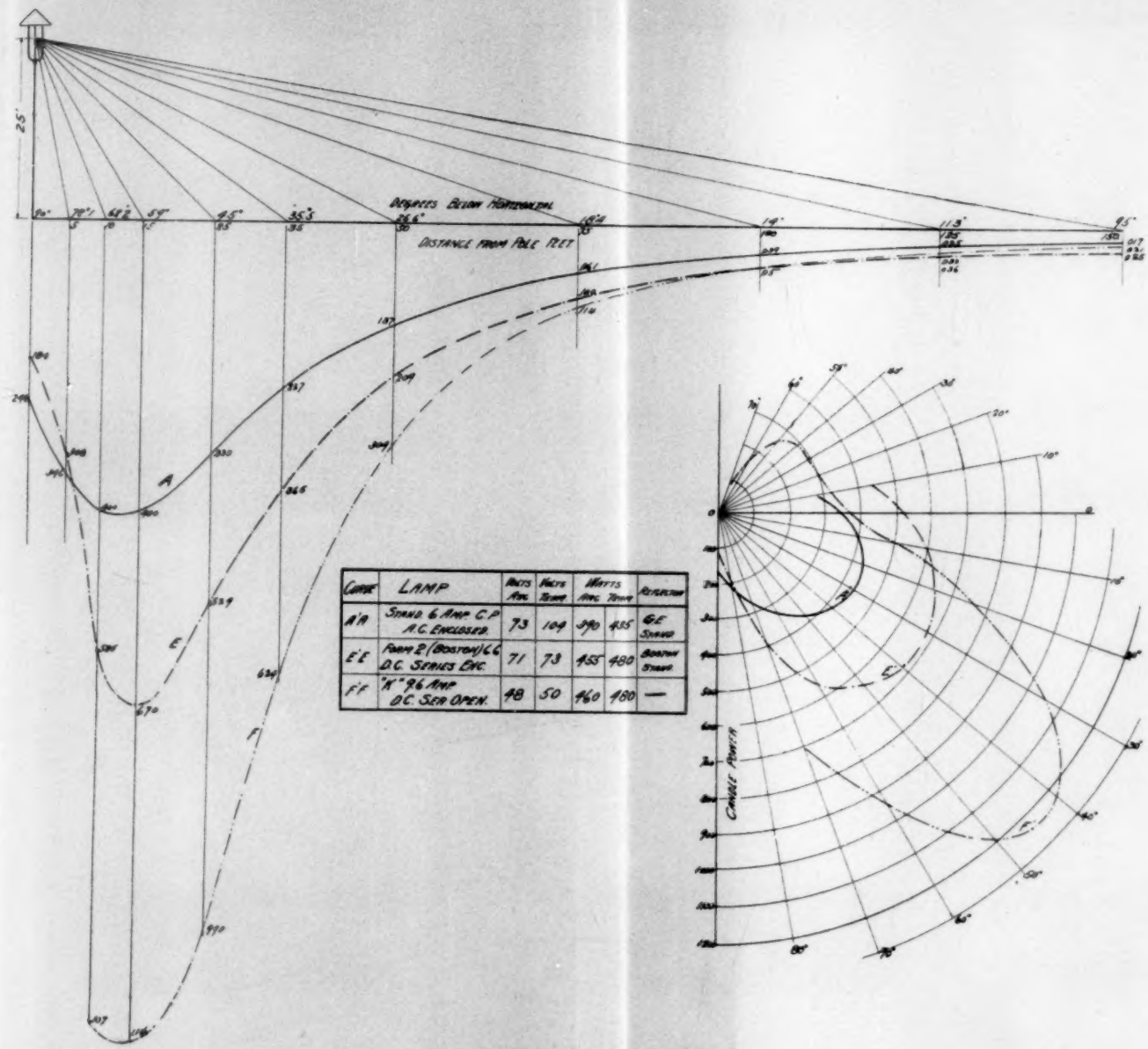
Messrs. S. M. Vauclain, John M. Hartman, Robt. F. Kinney, Geo. Hartley, the chairman, and a number of others participated. [The discussion is reported in full for future publication.]

DANIEL EPPELSHEIMER, JR., *Secretary.*

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday, October 17, 8 p. m. Professor Hoadley in the chair. Present, 42 members and visitors.

Messrs. Eglin and Hering spoke interestingly on "The Electrical Arts at the Pan-American Exposition." Mr. Eglin went into some detail concerning the progress which had been made by the Westinghouse Co. in perfecting the Nernst lamp, and an exhibition of the quality of these lamps was given with apparatus which had been allowed to remain in circuit since the regular meeting of the Institute. The fine quality of the light impressed those present very favorably. Slides were also shown illustrating some of the fine lighting effects at the Pan-American Exposition. Mr. Hering's remarks were to the effect that the novelties at the Exposition were rather few, but spoke regarding the progress which had been made in storage battery design, and also regarding the control of the circuit furnishing light to the Exposition, mentioning in detail the high potential switches and the number of lights in circuit.

RICHARD L. BINDER, *Secretary.*



Curve	Lamp	Watts Amp.	Watts Term.	Watts Amp.	Watts Term.	Reflector
A'A	Stand. 6 Amp. C.P. A.C. Enclosed.	73	104	390	485	G.E. Stand.
E'E	Form 2 (Boston) L.C. D.C. Series Enc.	71	73	455	480	Boston Stand.
F'F	"K" 9.6 Amp. D.C. Ser. Open.	48	50	460	480	—

FIG. 11.—ILLUMINATING CURVES.

(General Electric Company. Copyright by D'A. R. Ryan.)

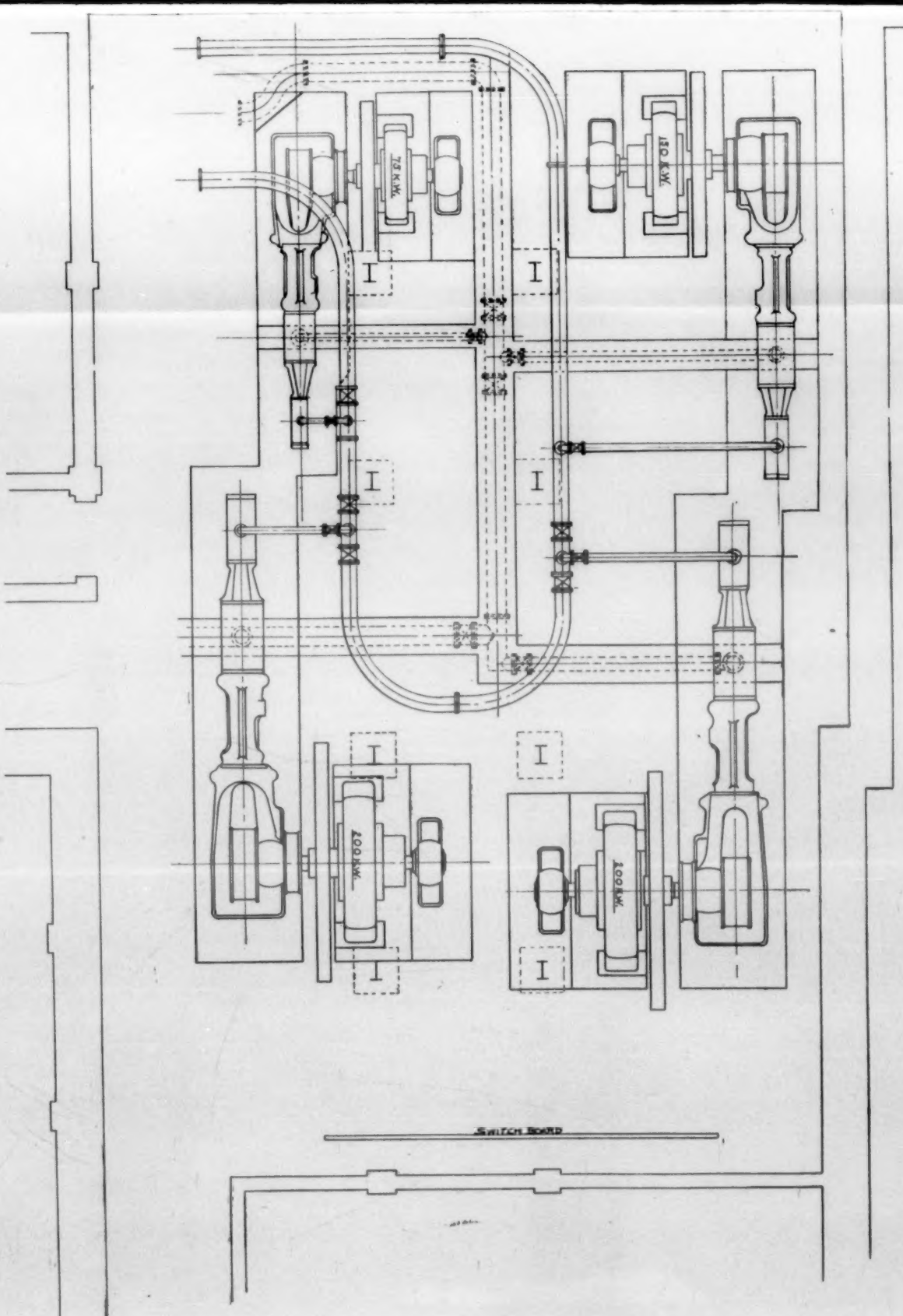
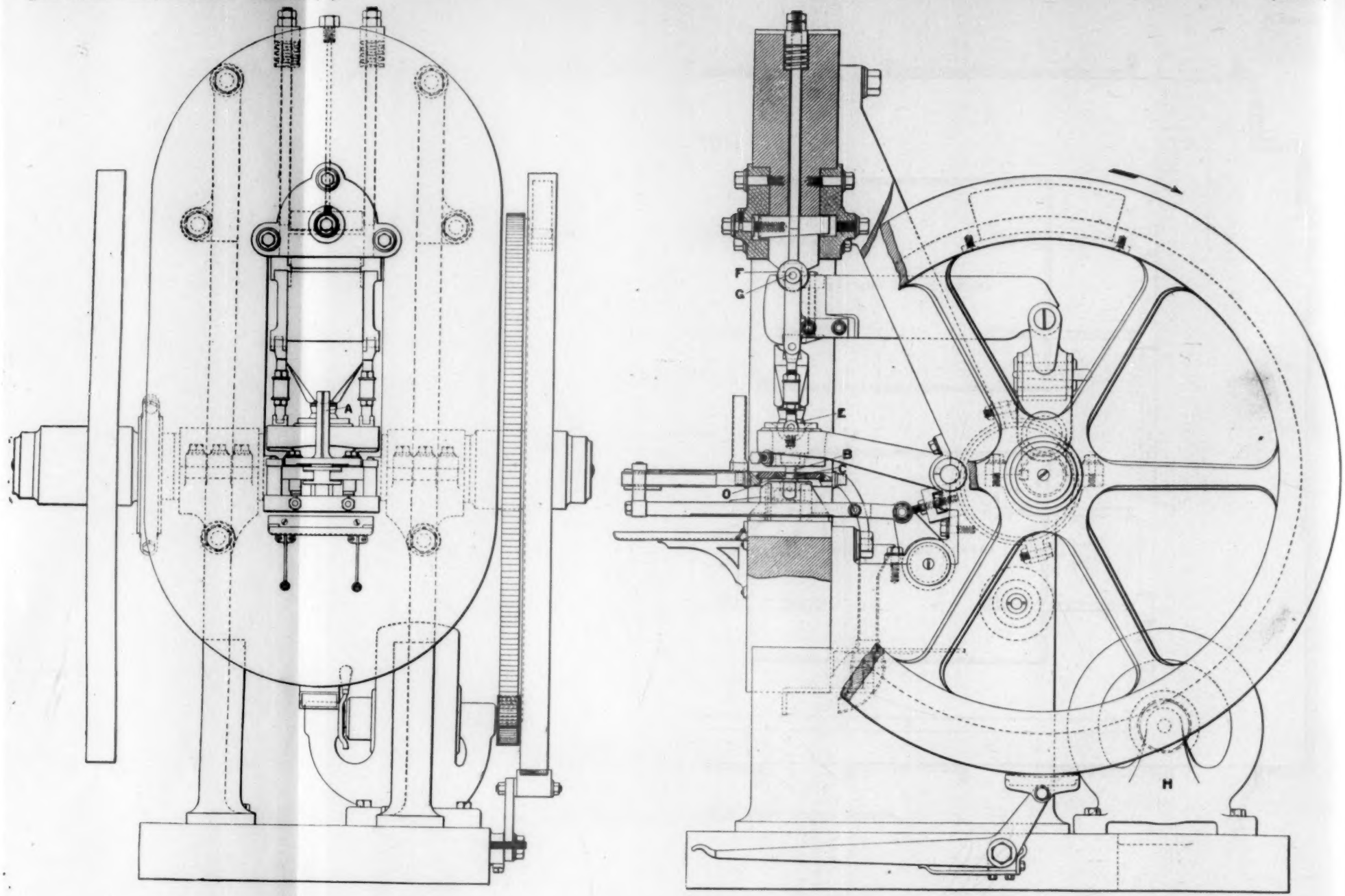


FIG. 13—PLAN OF ENGINE ROOM, U. S. MINT, PHILADELPHIA.

FIG. 13—PLAN OF ENGINE ROOM, U. S. MINT, PHILADELPHIA.



Front view. *Side view.*

FIG. 7—COINING PRESS.

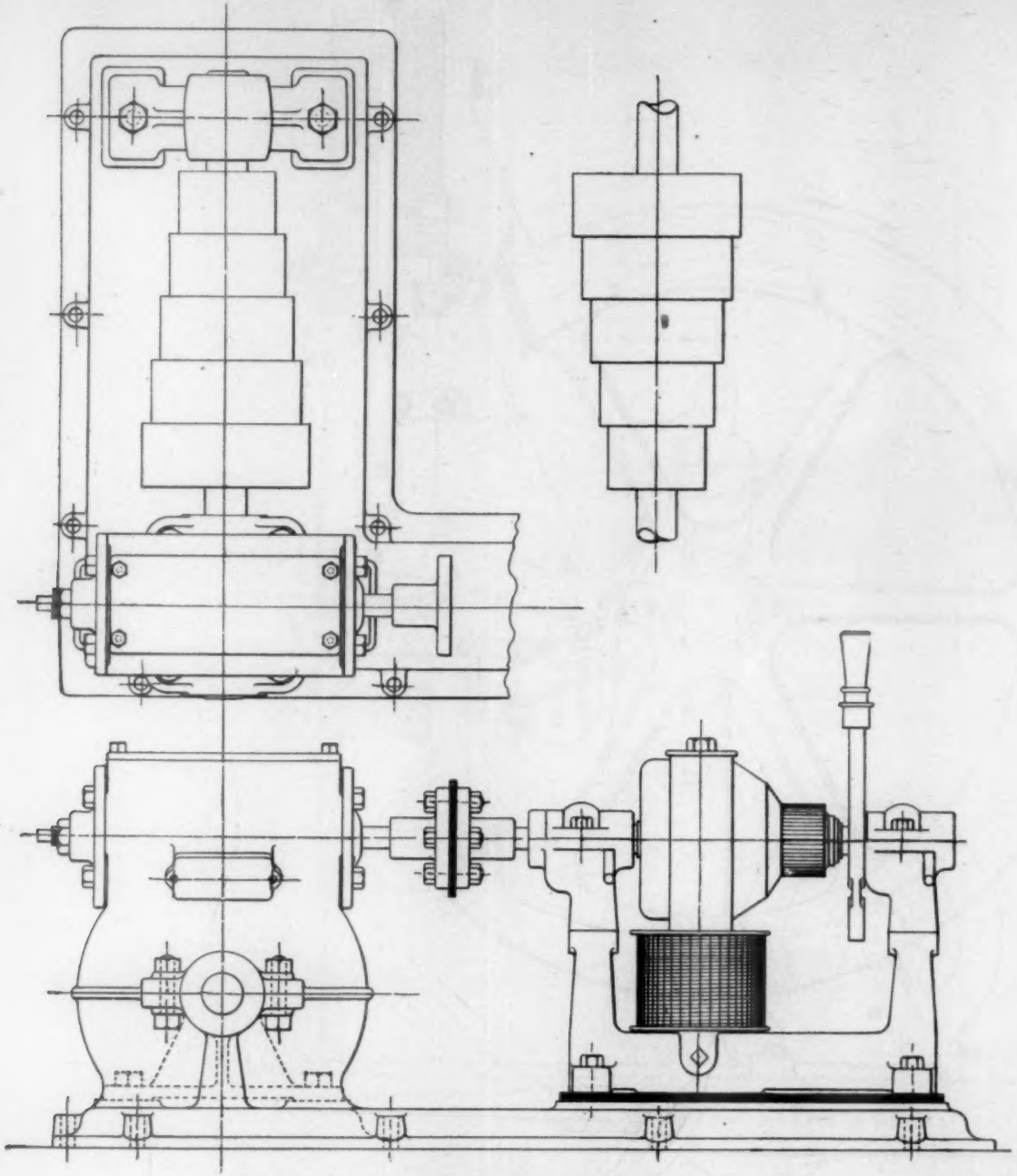


FIG. 3—WORM-GEAR DRIVE FOR THE ANNEALING OVENS.